FORTIETH ANNUAL REPORT

OF THE

NORTH CAROLINA

Agricultural Experiment Station

FOR THE

YEAR ENDED JUNE 30, 1917

FORTIETH ANNUAL REPORT

OF THE

NORTH CAROLINA

Agricultural Experiment Station

CONDUCTED JOINTLY BY THE

N. C. DEPARTMENT OF AGRICULTURE

AND THE

N. C. STATE COLLEGE OF AGRICULTURE AND ENGINEERING

FOR THE

YEAR ENDED JUNE 30, 1917

INCLUDING

Bulletin No. 237, and Technical Bulletins 11, 12 and 13

LETTER OF SUBMITTAL

RALEIGH, N. C., June 30, 1917.

To His Excellency, T. W. BICKETT,
Governor of North Carolina.

SIR:—I have the honor to submit herewith report of the operations of the Agricultural Experiment Station, conducted jointly by the North Carolina Department of Agriculture and the North Carolina State College of Agriculture and Engineering, for the year ended June 30, 1917. This work is under the immediate direction of the "Joint Committee for Agricultural Work," provided for in chapter 68 of the Public Laws of 1913, and amended by chapter 223 of the Public Laws of 1917, and the report is made in accordance with the requirements of the Act of Congress approved March 2, 1887, and known as the Hatch Act.

Very respectfully,

B. W. KILGORE,
Director.

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STAFF OF THE AGRICUTURAL EXPERIMENT STATION AND EXTENSION SERVICE

Administration

B. W. KILGORE .... Director of Experiment Station and Extension Service
C. B. WILLIAMS .... Vice Director, Experiment Station
R. W. COLLETT .... Assistant Director, Branch Stations
S. G. RUBINOW .... Assistant to Director
F. H. JETER .... Agricultural Editor
A. F. BOWEN .... Bursar
MISS S. D. JONES .... Bursar
MISS MARY S. BIRDSONG .... Secretary to Director

Agronomy

C. B. WILLIAMS .... Chief in Agronomy
J. K. PLUMMER .... Soil Chemist
W. F. PATE .... Agronomist-Soils
E. C. BLAIR .... Assistant Agronomist-Soils
J. O. WARE .... Assistant Agronomist-Soils
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C. C. LOGAN .... Extension Agronomist
[1]V. R. HERMAN, Assistant in Plant Breeding
[2]R. B. HARDISON .... Assistant in Soil Survey
S. O. PERKINS .... Assistant in Soil Survey
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[2]E. S. VANETTA .... Assistant in Soil Survey
S. F. DAVIDSON .... Assistant in Soil Survey
[1]E. H. MATTHEWSON .... Tobacco Expert
A. R. RUSSELL, Assistant in Field Experiments

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J. M. PICKELL .... Feed Chemist
W. G. HAYWOOD .... Fertilizer Chemist
J. Q. JACKSON .... Assistant Chemist
E. S. DEWAR .... Assistant Chemist
T. M. HILL .... Assistant Chemist
B. T. HORSFIELD .... Assistant Chemist

Entomology

FRANKLIN SHERMAN, JR., Chief in Entomoligy
Z. P. METCALF .... Entomologist
R. W. LEIBY .... Assistant Entomologist
J. E. ECKERT .... Assistant Entomologist
[6]C. L. SAMS .... Bee-keeping

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J. P. GRIFFITH .... Assistant Horticulturist
R. H. G. HILL .... Assistant Horticulturist
B. SZYMONIAK, Exten. Work—Horti. and Entomology

Animal Industry

DAN T. GRAY .... Chief in Animal Industry
R. S. CURTIS .... Associate in Animal Industry
W. H. EATON .... Dairy Experimenter
B. F. KAUPP .... Poultry Investigator and Pathologist
[3]A. J. REED .... Dairy Farming
[3]J. E. MOSES .... Pig Club Agent
[3]A. G. OLIVER .... Poultry Club Agent

STANLEY COMBES.................................Assistant in Dairy Farming
[3]J. A. AREY.................................Assistant in Dairy Farming
[3]F. R. FARNHAM.......................Assistant in Dairy Farming (Cheese Work)
[3]R. H. MASON.................................Assistant in Dairy Farming
[3]D. R. NOLAND.......................Assistant in Dairy Farming (Cheese Work)
[3]F. T. PEDEN.................................Assistant in Beef Cattle
[3]A. L. JERDEN.................................Assistant in Beef Cattle
[3]L. I. CASE.................................Assistant in Beef Cattle
EARL HOSTETLER.......................Assistant in Beef Cattle and Swine
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J. E. IVEY.................................Assistant in Poultry Investigation

Plant Pathology

F. A. WOLF............Plant Pathologist
R. O. CROMWELL, Assistant—Plant Diseases
E. E. STANFORD..Assistant in Becteriology
A. C. FOSTER..Assistant in Plant Diseases

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F. R. BAKER..Assistant Drainage Engineer

Veterinary

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J. I. HANDLEY.................................Assistant Veterinarian

Markets and Rural Organization

W. R. CAMP.................................Chief, Division of Markets
O. J. MCCONNELL.......................Assistant in Cotton Grading and Marketing
J. A. LIVINGSTONE.......................Assistant Superintendent of Credit Unions
BOLLING HILL.......................Assistant in Marketing Fruits and Vegetables

Farm Management

[5]J. M. JOHNSON.................................Farm Management

Branch Stations

R. W. COLLETT.......................Assistant Director, in Charge Branch Stations
F. T. MEACHAM................Assistant Director Iredell Branch Station, Statesville
R. G. HILL.................Assistant Director Pender Branch Station, Willard
C. E. CLARK..............Assistant Director Edgecombe Branch Station, Rocky Mount
E. G. MOSS.......................Assistant Director Granville Branch Station, Oxford
S. C. CLAPP................Assistant Director Buncombe Branch Station, Swannanoa
H. BOCKER....................Assistant Director Black Land Branch Station, Wenona

Farm Demonstration Work

C. R. HUDSON.................................State Agent
E. S. MILLSAPS.......................District Agent, Western District
T. D. MCLEAN.......................District Agent, Central District
R. W. FREEMAN.......................District Agent, Southeastern District
J. M. GRAY.......................District Agent, Mountain District
O. F. MCCRARY.......................District Agent, Northeastern District

Boys' Agricultural Clubs

T. E. BROWNE.................................State Agent and Rural Supervisor
A. K. ROBERTSON.................................Corn Club Agent
A. G. OLIVER.................................Poultry Club Agent
[1]J. E. MOSES.................................Pig Club Agent
W. KERR SCOTT.................................Assistant Club Agent

Home Demonstration Work

MRS. JANE S. MCKIMMON.................................State Agent
MISS MINNIE L. JAMISON.......................Assistant in Home Demonstration Work
MISS LAURA M. WINGFIELD.......................District Agent, Central District
MISS LIZZIE J. RODDICK.......................District Agent, Eastern District
MRS. J. H. HENLEY.......................District Agent, Unorganized Territory

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The members marked with * are members of the Joint Committee for Agricultural Work, and the Experiment Station and Extension Service are under their direction.

[1]In coöperation with the U. S.Department of Agriculture, Bureau of Plant Industry.

[2]In coöperation with the U. S. Department of Agriculture, Bureau of Soils.

[3]In coöperation with the U. S. Department of Agriculture, Bureau of Animal Industry.

[4]In coöperation with the U. S. Department of Agriculture, Office of Public Roads and Rural Engineering.

[5]In coöperation with the U. S. Department of Agriculture. Office of Farm Management.

[6]In coöperation with the U. S. Department of Agriculture, Bureau of Entomology.

FORTIETH ANNUAL REPORT

OF THE

North Carolina Agricultural Experiment Station

For the Year Ending June 30, 1917

B. W. Kilgore, *Director.*
F. H. Jeter, *Agricultural Editor.*

This report covers the activities of the Agricultural Experiment Station, conducted jointly by the North Carolina Department of Agriculture, the North Carolina State College of Agriculture and Engineering, and in coöperation with the United States Department of Agriculture, for the year beginning July 1, 1916, and ending June 30, 1917.

Much progress has been made on all the projects or studies which are being conducted by the Station and much additional original information has been secured as a result of the experimental inquiries. The workers in the various divisions have been faithful and efficient in the discharge of their duties and have endeavored to advance in every way possible the cause of improved agriculture for the entire State.

Working through the staff of the Extension Service, the information which has been obtained has been disseminated over the State and has been reflected in a substantial betterment of improved farming conditions. The Experiment Station is entering more and more into the life of the farming public and is more and more being called upon for leadership in solving those problems peculiar to North Carolina.

A number of changes in staff have occurred. Most of these have been due to the patriotism of assistants who have felt the call of their country and have left to serve in other ways than those offered by work of agricultural investigation. The men who have severed their connection with the staff have accepted service in the National Department of Agriculture or have volunteered for service in some branch of the Nation's fighting forces. These have been:

L. I. Case, in service.
T. M. Hill, in service.
A. L. Jerdan, in service.
H. D. Lambert, in service.
J. R. Mullen, in service.
F. C. Wiggins, in service.
E. E. Culbreth, commercial work, North Carolina.
S. C. Clapp, transferred to Branch Experiment Station, Buncombe County, N. C.
B. P. Folk, farming.
E. B. Hart, Southland Cotton Oil Co., Paris, Texas.
R. G. Hill, U. S. Department of Agriculture.
J. H. Jefferies, farming.
F. N. McDowell, transferred to County Agent, North Carolina.
G. H. Rea, Department of Agriculture, Pennsylvania.
E. E. Stanford, Bureau of Chemistry, U. S. D. A.

The Station has pursued a line of policy in conformity with that of previous years, that is of attempting to keep somewhat in advance of the demands which are actually made upon it for information. Since the entering of this country into hostilities, however, efforts have been made to put the investigational work on a war footing, studying problems relating principally to the abnormal conditions occasioned by our entry into the world conflict. These efforts have taken the form of increased production of food and feedstuffs as they relate to soil fertility, crop rotations, fertilizing problems, the control of insects and plant and animal diseases, the maximum production and conservation of meats and the study of problems connected with organizing and saving. All of these and others have been given special consideration; and, in addition to this, many facts gathered by previous experimental work have been given to the people of the State through the Extension workers, through the different publications of the Station, through the press of the State and through magazines of local and national importance.

It is timely, also, at this point to mention the fact that the best of coöperation has been given the Station by the State press, by the coöperative institutions and by various commercial and industrial organizations. The program of work to which the Station committed itself at the beginning of the war has been published in every leading paper of the State and later the findings of experiments have been as willingly published and circulated. One paper issued a special edition during the year in which the work was outlined by the heads of the different divisions, and was published in its entirety.

The Station workers, forty-eight in number, have been prominent at meetings originated by the Extension Service or other organizations and individuals, and have given the results of carefully planned and conducted experiments in such a manner as to lend weight and authority and to give help to present agricultural needs. The farmers of the State are doing their part heroically in the production of food and feedstuffs for the supply of a hungry world. They have called upon the Station more during the past year than at any previous time in the history of the State, and through the Extension Service, with which the Station is closely allied, they have been served as efficiently as possible.

The different divisions have worked out much authoritative data on many of the different questions concerning farming and advanced agricultural operations and a resumé of this work may be found in the accompanying reports which are submitted. It will be seen that the program of these investigations is being developed to meet the needs of a constantly growing agriculture and to furnish helpful information in such places as it will be of most benefit.

AGRONOMY.

The Division of Agronomy is making good progress under the four different lines of work to which it is devoting particular attention. These four lines are (1) the study of the soil characteristics of the soils of the State, which are being mapped in a systematic manner; (2) a study of the plant food requirements of the important soils; (3) crop rotation studies in which rational systems of rotations for the purpose of affording financial returns, as well as the gradual building up of the soils to a higher state of fertility is being worked out, and (4) crop improvement studies in which seed selection and breeding work enter largely.

Since the last report, surveys have been made and reports have been prepared for Cleveland, Beaufort and Stanly counties; and, Bertie and Orange counties have been more than half mapped. At the present time parties are at work in two other counties, Caldwell and Wilkes. This work is of vital importance to agriculture in North Carolina as it furnishes a definite and reliable basis for positive recommendations in regard to the handling of farm lands in counties where the surveys have been made and where experiments have been conducted on similar soil types elsewhere or in that same county.

In field experiments, the plant food deficiencies and needs of the soils of the State are being studied after the soil type has been determined. In addition to the plots on the central station farm and the branch station farms, this work is being done on seventeen different types of soil in private fields located in sixteen different counties; also eleven of the State farm-life schools have this work on their farms. Interesting phases of this same study are being developed in pot culture experiments, being made by the Soil Chemist.

In the improvements of crops, progress has been made to the extent that several of the Station farms are being stocked with high grade, pure bred seed, selected and improved by the Division. Corn, cotton, peanuts, soybeans, cow peas and the small grains, such as wheat, oats and rye, have all received a share of this work.

The systematic publication of county soil reports has been begun and reports of this character have been issued as State Department of Agriculture Bulletins for Mecklenburg, Gaston, Union and Cabarrus counties. These reports give definite information in regard to the agriculture, climate and soils of the counties.

CHEMISTRY.

In addition to work with the nitrification and ammonification in soils in which the studies have been made largely with solutions, work in the Division of Chemistry has centered largely around the determination of the toxicity of cotton seed and its products. The Division has published five important articles in regard to the toxic principle of

cottonseed meal, kernels and other parts of the cotton plant, and has designated the toxic principle found in these as gossypol. Experiments have been made on various animals showing that this substance does cause the poisoning of swine and other animals and indicating that the explanations offered by other investigators that the injury is similar to beriberi and is caused by deficiency in diets, insufficient minerals or insufficient supplies of other soluble growth-promoting substance are not correct. It is also found that gossypol appears to be a constituent of the cotton plant only.

It has been found that the addition of iron in the form of ferrous sulphate and ferric chloride to cottonseed meal in feeding swine exerts a beneficial action. Wood ashes, however, do not seem to exercise to any extent beneficial effect in overcoming this toxicity of the meal.

ANIMAL INDUSTRY.

The investigational work of the Animal Industry Division is being conducted with swine, beef cattle, dairy cattle, sheep, horses and mules, and poultry. In the experiments with these animals, the main problems connected with their handling, production and feeding have been studied, except in the case of horses and mules, where insufficient funds made complete work with these inadvisable; however, all of the animals on the branch station farms are being fed cottonseed meal to replace corn in the daily ration, and the observations and records are being made. It has been found that the meal can replace a considerable amount of corn—feeding work stock.

Work with swine has centered largely around the use of pasturage for the cheaper production of pork. Soybeans, peanuts, and other crops have been used and the effect on the bodies of the animals has been carefully studied. It has been found that even where soft-bodied hogs are produced, these may be hardened by varying the rations before the animals are marketed. Two other problems concerning the cost of raising pigs to the weaning age, and the home curing of meat, have received considerable attention during the year and valuable information has been secured.

With beef cattle, the principal investigative projects have centered around the study of trembles, or milk sickness, and which, experiments indicate, is caused by a weed known as white snake root; and the feeding and wintering of steers on corn silage, peanut meal and various other rations in different parts of the State. The work being done on the farm of T. L. Gwyn, at Clyde, has probably exercised more influence in the State than any other, as here, there is a large supply of cattle available for studying the various methods of getting the steers through the winter months. Fine results have attended the work on this farm and the results have been given to the State from time to time.

Sheep work has been placed on a better basis during the past year

and investigations are now being conducted in Mitchell County, in addition to the central station farm and Iredell farm. This work centers largely around breeding of pure bred animals, eradication of the stomach worm and the winter feeding of ewes. The sheep is about the only animal which does not compete with man in the feed consumed, and in addition they furnish a quick means of increasing the meat supply, and for this reason the live stock workers are doing everything possible to encourage farmers to get more and better rams and breeding ewes. This request is being met with a favorable response.

In dairy cattle work a study of onion contamination of milk and the making of home cheeses has occupied the principal attention. Feeding problems, growing problems and other manufacturing problems are also being investigated. There has been a large growth in the mountain cheese industry.

The poultry work continues to be an important part of the investigational work of the Animal Industry Division. A large number of problems are, at present, being studied, and the utilization of grazing crops for poultry are being carefully investigated, as well as the building of hen houses, conserving of eggs and combating poultry diseases, which every year cause such enormous losses.

ENTOMOLOGY.

Investigational work in Entomology centers largely around the study of pecan insects, the corn-stalk borer, the spraying of potatoes and peaches, a survey of the insect life of the State, the study of the black corn weevil, the southern corn bill bug, the cow pea weevil, and the corn root worm. Good progress has been made along all lines of this work. The study of the pecan insects has proven especially valuable, as it is going along hand in hand with the development of the pecan industry of the State. Especial mention might be made of the injury by the pecan leaf case-bearer, which seriously injured many trees during the past year. Since the life history of this insect has been studied, satisfactory control was applied before much injury was done.

The study of the insect life of North Carolina is progressive favorably and many instructive facts have been placed on record in regard to the insects of the State. A study on the southern corn bill bug has been closed and the results published in Technical Bulletin No. 13. It is also found that cow peas may be treated by ordinary lime to prevent weevil injury, and a detailed report has been made of these results in the *Journal of Economic Entomology*. Investigations have indicated that the best date for sowing wheat in North Carolina is approximately October 15th. If sown earlier, it is liable to injury from the Hessian Fly.

Another project of interest has been that of bee-keeping work which was begun a year ago. At that time the bee-keepers were without organi-

ation, leadership, or official recognition; and at this time, under the leadership of a competent worker, much work is being done and the bee-keepers have been organized into a State Bee-keepers Association, which has its membership from over the entire State.

HORTICULTURE.

In Horticulture, the principal work of the year has been in the investigation of pecan varieties suitable for commercial purposes in North Carolina, the breeding of those varieties especially fitted to the State, the importation and testing of edible nuts, experiments with truck crops, including rotations, variety tests, different methods of cultivation and storage problems, especially with sweet potatoes at the Pender Trucking Branch Station.

Another feature of interest has been a study of what is known as Thermal Belts, in the western part of the State. This has been done in coöperation with the Weather Bureau. Considerable data also have been secured in the work with peaches on the various branch station farms and at Southern Pines. A bulletin was published covering this work as a State Department of Agriculture Bulletin in December, 1916, and has proven very useful.

In the investigations made with the rotundifolia grapes, considerable progress has been made and the reports on this work have constituted a distinct addition to the literature on the subject of heredity and have been widely copied in journals. Something over 4,500 seedlings have now been secured by hand crossing and the most promising of these have been transplanted to permanent places. This work, in addition to the special work being done at the Pender Branch Station in coöperation with the U. S. Department of Agriculture to improve the scuppernong type of grape, is adding much valuable data to the records of the Station.

VETERINARY SCIENCE.

In this Division the principal work has been in the study of the prevalence and control of "contagious abortion." This has been done in herds of cattle, in horses, swine and sheep out over the State and in laboratory examinations at the Station. In addition to this, workers have been called upon to perform autopsies on animals under experiments for other divisions; visits were made to sick animals of the State; and slaughter examinations were made on experimental animals to be used for market purposes.

PLANT PATHOLOGY AND BACTERIOLOGY.

Investigations in this Division have been centered largely on tobacco wilt and its control, apple root rots, lettuce drop, watermelon wilt and the production of varieties resistant to wilt; soybean and cow pea wilt and other studies, some of which are being made in connection with the

other divisions of the Station. Among these is the determination of the cause of trembles, or milk sickness in animals in western North Carolina and the experiments have shown this to be produced by a weed known as the White Snake Root or eupatorium urticæfolium.

It has been found that soybeans are affected with a wilt or blight disease, caused by an organism identical with that which causes cow pea wilt.

The results of the tobacco wilt work are reported in Bulletin 562 of the U. S. Department of Agriculture, in coöperation with this Station, and show that a proper system of rotation is necessary for its successful control.

The other activities of the Division have been in making a plant disease survey in the State and in contributing information relative to the more common plant diseases.

MARKETS AND RURAL ORGANIZATION.

The Division of Markets has concerned itself as heretofore with a study of matters relating to grading, marketing and financing. Investigations of prices received by farmers for various commodities, the proper marketing of these commodities, the issuance of weekly price reports, and market news service, the forming of marketing and credit associations and the grading and classing of cotton have been among the main studies involved. The daily market wire service maintained during the year in coöperation with the Bureau of Markets of the Federal Department of Agriculture for Irish potatoes, sweet potatoes, cantaloupes, watermelons and apples, proved to be of tremendous value to growers in preventing the shipping of much perishable products to markets already overcrowded.

The listing of buyers and sellers of farm produce has also been an important activity.

Growers, buyers, and mills have become interested in the cotton grading work and the commissioners of eight of the leading cotton-producing counties have made the necessary appropriation to conduct this work this year. This grading work has shown that a large part of the cotton produced in this State is above middling, and it has been the means of saving cotton growers considerable money by furnishing them with this knowledge. The cotton grading and marketing work is coöperating with the Bureau of Markets of the Federal government.

The Division has coöperated with the Federal Land Bank at Columbia by aiding in the organization of Farm Loan Associations and in forwarding applications for loans to the bank.

DRAINAGE.

Five major lines of investigations have occupied the activities of the Division of Drainage during the past year and these may be grouped under the headings of (1) farm drainage and terracing surveys and

investigations relative thereto, such as the proper spacing and depth of under drains, or the methods of arrangement and spacing of terraces on slopes where needed; (2) the collection of run-off data in drainage canals; (3) preliminary examinations and reconnaissance work for large drainage undertakings; (4) maintenance work on drainage canals and (5) studies relating to the efficiency of under drains. Along all of these lines considerable work has been accomplished and many facts of importance recorded.

During the year preliminary surveys, and reports for tile drainage systems have been made on twenty-seven farms in eighteen counties, comprising a total area of 12,000 acres. Over 18,500 acres have had preliminary or reconnaissance examinations made. Examinations have also indicated that new drainage canals should require annual attention only after having been in use for a period of three or four years. This attention requires the removal of silt, weeds, logs and other obstructions, so that the water may be confined to a straight, narrow channel.

PUBLICATIONS.

Many multigraph circulars and letters relating to the work of the Experiment Station have been distributed to select mailing lists during the past year. The press has also been furnished with the findings of the Experiment Station and considerable data have been published in the *Extension Farm News*. Much effort was made along publicity lines with a view to increasing food production in the State and conserving it after being produced. Both the weeklies and the dailies have coöperated in using the matter sent out from the Station.

One bulletin, No. 237, "Tobacco Culture in North Carolina," with forty pages, and 15,000 copies was issued. Three Technical Bulletins, Nos. 11, 12, and 13, with a combined issue of 16,000 copies; and two circulars, Nos. 34 and 35, with a combined issue of 11,000 copies, have also been printed and mailed out.

The total number of names in the mailing lists now approximates 75,000, and it is attempted to keep these lists up to date.

The following are the publications issued:

BULLETIN

No. 237. Tobacco Culture in North Carolina. *By E. H. Matthewson and E. G. Moss.*

TECHNICAL BULLETINS

No. 11. Self Sterility in Dewberries and Blackberries. *By L. R. Detjen.*
No. 12. Inheritance of sex in Vitis Rotundifolia. *By L. R. Detjen.*
No. 13. Biological Investigation of Sphenophorus Callosus Oliv. *By Z. P. Metcalf.*

EXPERIMENT STATION CIRCULARS

No. 34. Soybean Products and Their Uses.
No. 35. Velvet Beans—How to Grow and Use.

The reports of the heads of the several Divisions and financial statement follow:

FINANCIAL REPORT

THE NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION

in account with

The United States Appropriations, 1916-1917.

Dr.

	Hatch Fund	Adams Fund
To receipts from the Treasurer of the United States, as per appropriations for the fiscal year ended June 30, 1917, under acts of Congress approved March 2, 1887 (Hatch Fund), and March 16, 1906 (Adams Fund	$ 15,000.00	$ 15,000.00

Cr.

	Hatch Fund	Adams Fund
Salaries	$ 7,540.00	$ 12,423.06
Labor	3,457.84	438.74
Postage and stationery	283.55	169.77
Freight and express	94.51	67.32
Heat, light, water, and power	236.43	172.14
Chemicals and laboratory supplies	164.30	416.35
Seeds, plants and sundry supplies	539.81	228.11
Fertilizers	567.57	120.35
Feeding stuffs	658.10	204.88
Library	100.00	
Tools, machinery, and appliances	200.00	
Scientific apparatus and specimens	27.25	218.65
Live stock	146.50	108.05
Traveling expenses	218.12	432.58
Contingent expenses	20.00	
Buildings and land	746.02	
Total	$ 15,000.00	$ 15,000.00

THE NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION

in account with

FARM AND MISCELLANEOUS RECEIPTS.

DR.

Receipts from other sources than the United States for the year ending June 30, 1917		$5,506.77

Supplemental Statement.

CR.

Labor	$ 596.50	
Publications	265.30	
Postage and stationery	5.10	
Heat, light, water, and power	53.38	
Chemicals and laboratory supplies	63.97	
Seeds, plants and sundry supplies	73.62	
Fertilizers	796.20	
Feeding stuffs	1,431.11	
Library	209.15	
Tools, machinery and appliances	263.28	
Furniture and fixtures	158.33	
Traveling expenses	179.64	
Contingent expenses	40.00	
Buildings and land	571.79	
Balance	839.00	
		$5,506.77

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the North Carolina Experiment Station for the fiscal year ending June 30, 1917; that we have found the same well kept and classified as above, and that the receipts for the year from the Treasury of the United States are shown to have been $30,000, and the corresponding disbursements $30,000, for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving nothing.

And we further certify that the expenditures have been solely for the purposes set forth in the acts of Congress, approved March 2, 1887, and March 16, 1906.

(Signed) W. H. RAGAN,
W. E. DANIEL,
T. T. THORNE,
Auditors.

(Seal)
Attest: A. F. BOWEN, Custodian.

REPORT OF THE DIVISION OF AGRONOMY.

To the Director:

During the year, workers of the Agronomy Division have been quite active, and considerable information of a permanent nature has been secured and given to the people. As heretofore, the main work of the Division has been in mapping the soils of the State in a systematic way; in studying the plant-food requirements of the different types as found in different parts of the State; in working out rational systems of crop rotation that may be used, not only for affording good immediate financial returns but also for building up the fertility of the soil; and in the improvement of many of our farm crops by the use of proper methods of seed selection.

FIELD STUDY AND CLASSIFICATION OF SOILS.

In order that the results of experimental work may be applied intelligently, not only is it necessary to know definitely the types of soil on which the work is being conducted, but in addition, it is very essential in giving advice to farmers in talks at farmers' meetings, in writing bulletins, in answering correspondence, and in other ways to know the type of soil to which the results are applicable. It is not generally safe to make any iron clad recommendations for the State with reference to the plant-food needs of soils. Even in the Piedmonth section it has frequently been found that with some soils the plant-food requirements are quite different from other types occurring in the same county and in close proximity.

Realizing the necessity for having definite information with reference to soils and the boundaries of the different types in the several counties of the State, soil survey work was started in North Carolina many years ago. This work has been pushed actively during the past four or five years. At the present time there are three State and three Federal men devoting their time entirely to this work of identifying and mapping the soils. It is a source of considerable pride that North Carolina was one of the first states to take up this work in a systematic way. It is generally recognized that the work in North Carolina is being conducted in as systematic and intelligent manner as is being done in any other state in the Union. This work is being carried on in coöperation with the Bureau of Soils of the U. S. Department of Agriculture.

Since the last report, surveys have been made and reports prepared for publication for Stanly, Cleveland and Beaufort counties. At the present time field parties are at work in Caldwell, Wilkes and Orange counties. The work in these is nearing completion at the present time Bertie County has been more than half mapped, but work on it had to be discontinued on account of the field man getting sick.

The following are some of the ways in which the soil survey work has proven of value to farmers and agricultural workers of the State in their work with farmers:

1. It provides county agents and other Extension workers with definite first-hand reliable information with reference to the general agriculture existing in the county and section in which they may be working at any time.

2. It provides all agricultural workers with a definite basis on which to apply the results which have been secured or may be obtained in the future in experimental work to the different types of soil of the State.

3. It has not been an infrequent thing to find farmers who have been living on a certain type of soil and who were spending their time and money in experimenting on some problem which had already been worked out by the Experiment Station. Time and money might have been saved such persons had they known of certain results published by the Station for a certain type of soil which were directly applicable to their farms because their soils were of the same type as those studied. In all probability, therefore, the needs were the same, in the main, for the most profitable and economical growing of crops.

4. It enables a farmer living in a county where a soil survey has been made and a report issued to describe his soil in a definite way so that the person answering an inquiry may do so most intelligently, rendering the greatest service.

5. Farmers are demanding definite and specific information with reference to the needs of their soils. As indicated above, it is only possible for us to supply this in the most satisfactory way by having the soil survey results on the leading types of soil.

6. The survey is valuable in that it gives those who are growing specialized crops an idea as to where they may find soils best suited for the growing of these special crops in other communities of the State other than those of their own. This information is valuable for supplying to those outside who are seeking to buy lands within the State, especially who wish to grow special crops.

7. The chemical analyses of soils gathered in the soil survey give, in a definite way, the total amount of plant-food constituents in the soils. With this information a safer idea may be found of the plant-food requirements of any particular soil than would otherwise be the case if sole dependence was put upon the results of field trials. It has been found in some cases that with soils very low in one of the plant-food constituents, growing crops do not show this to be the limiting factor at the present time. As it requires a certain amount of each of the different plant-food constituents to produce a unit weight of crops, it is not difficult to calculate that with such soils constituents as are contained in very small quantities, it will not be long before these will become limiting factors, if provision is not made for supplying them in available form. Again the analyses, as is the case

with the Cecil series of soils in the Piedmont section of the State, show that in many cases the plant-food constituents which are contained in least quantities in the soil are the ones that are at present time the limiting factors in crop growth. For instance, with these soils the content of nitrogen and phosphoric acid is low and field experiments show, too, that in order to get the best paying results with these soils generally, materials carrying these two constituents in available form must be supplied to the soil of this series.

Working out the Deficiencies and Needs of Our Soils.—In order to determine the needs of the leading types of soil of the State, there has been put out on these a large number of field experiments, which were designed to work out the limiting factors in crop growth, with particular reference to their plant-food deficiencies and needs when different crops were grown on them. This work is being carried on by the Division of Agronomy in a detailed way on the Central Farm at Raleigh, and on the Test Farms located at Swannanoa, Statesville, Oxford, Willard, Kingsboro and Wenona. Supplementing this work, there are soil-type fields located in different parts of the State on different types of soil. These latter experiments are carried on in coöperation with the farmers who have farms on the type of soils to be studied, and who are sufficiently interested and patriotic to take the necessary pains to see that the details of the work are properly carried out. In this latter work, close and sympathetic supervision is exercised by the Division. An employee of the Division is always sent to see that the fertilizer is weighed out and put in properly on the right plots and that the seed are planted as should be in work of this kind. During the growing season, visits are made to these fields to see that the work is progressing satisfactorily and to take notes on the growth of the crop on the different plats. At the end of the growing season the crop is harvested and weighed by some one connected with the Division.

The soil-type fields are conducted on the following types of soil and in the counties indicated:

Soil	*County*
Porter's Clay	Transylvania
Toxaway Silty Loam	Cherokee
Porter's Loam	Buncombe
Toxaway Loam	Buncombe
Cecil Clay Loam	Iredell
Cecil Sandy Loam	Gaston
Iredell Loam	Mecklenburg
Mecklenburg Clay Loam	Cabarrus
Cabarrus Silt Loam	Union
Durham Sandy Loam	Granville
Norfolk Coarse Sand	Richmond
Norfolk Sand	Pitt
Norfolk Fine Sandy Loam	Edgecombe
Coxville Silt Loam	Perquimans
Portsmouth Fine Sandy Loam	Washington
Muck	Currituck
Norfolk Fine Sandy Loam	Pender

In connection with many of the Farm Life schools, demonstration experiments have been started on the types of soil prevailing on the farms connected with these schools. It is believed that this work will not only help up determine the plant-food requirements of the soils studied, but the results secured will be of much value to the teachers of Agriculture in these schools in their class work. Not only this, but such work should be an effective means of interesting the patrons of the schools in the work of the farm, as the lessons taught by the results should be of value to many of them in their farming operations.

At the present time this work is being conducted in coöperation with the following schools of this type:

School	*County*
Pleasant Garden Farm Life School	Guilford
China Grove Farm Life School	Cabarrus
Lowe's Grove Farm Life School	Durham
Parris Agricultural High School	Durham
Red Oak Farm Life School	Nash
Philadelphus Farm Life School	Robeson
Sand Hill Farm Life School	Moore
Jamestown High School	Guilford
Farm Life School	Craven
Dallas Farm Life School	Gaston
Wakelon High School	Wake

In all of these tests there is included a plot to study the value of stable manure as a carrier of nitrogen. The tests at the farm life school at Dallas have been planned mainly to work out the value of different amounts of lime applied to soils when leguminous crops suitable for growth in that section are grown each year in rotation. On this field, as well as those at the Central Farm at Raleigh, the amount of lime per acre used is varied from 2,000 pounds of calcium carbonate to 8,000 pounds per acre. In the experiments, the lime has been used in connection with what is considered a requisite amount of available phospohric acid to meet the needs of the growing crop. To give an idea of the rotation which is being used, the one planned for use at the Central Farm might be given as an example. It is as follows:

First year—Velvet beans sown in the spring, followed by a fall seeding of rye.

Second year—Corn, with cowpeas sown in the corn and followed by a seeding of oats and vetch in the fall.

Third year—Oats and vetch, followed by soybeans in summer and red clover in fall.

Fourth year—Cotton, with crimson clover sown just before or just after the first picking.

Soybean meal has been added to the list of those nitrogenous materials, which the relative value is being studied, as carriers of nitrogen as a plant-food constituent for crop growth. This would seem advisable in view of the fact that a goodly amount of soybeans have

been crushed by the oil mills of the State during the past two years and this meal is being sold largely for fertilizing purposes. The tests are being conducted on the Iredell, Edgecombe and Central farms.

At the Wenona test farm on muck soil, fertilizer experiments have been conducted to study the plant-food needs of this type of soil at the present time. In these experiments which have now been conducted for two years, there are included those that had different fertilizer combinations with and without lime. During the spring, more detailed lime experiments were put out on this farm to study the relative value of different carriers of lime, and to determine the best quantity per acre to use in order to get the best paying results. The applications, per acre, have run from two to eight tons of calcium carbonate from marl per acre. Other plots carrying other forms of lime have been put out carrying the same equivalents of actual lime.

At the Buncombe Farm in the rotation plots, wheat has been grown every year with an application of a complete fertilizer on one of the plots. The yields on this plot have steadily decreased. On the checked plot to which no fertilizer has been applied, the yields are so small at the present time that it is practically impossible to harvest the wheat. The yields on the plot receiving an application of stable manure are holding up very well. The plot which has received an application of lime in connection with a complete fertilizer and where red clover is used in the rotation, the yields have steadily improved. The value of lime in promoting the growth of legumes on practically all of the plots at this farm has shown up more markedly during the past year or so than formerly.

The rock phosphate experiments have shown fairly good yields, but in no case has this phosphate given as large yields or as profitable yields as acid phosphate when used alone, with manure, with potash and legumes, or with lime-potash-and-legumes. From the study thus far of Mountain soils, it has been found that phosphoric acid is the constituent of first importance. Next, nitrogen will come generally and lime with upland soil, and lime and nitrogen with bottom soils. The nitrogen is not nearly so important a constituent to be added to the bottom soils as it is with soils in the uplands.

Generally, the soils of the Piedmont section show the greatest lack of nitrogen, phosphoric acid and lime. These constituents at the present time are, therefore, the limiting factors in the most profitable plant growth. Very little benefit ordinarily with general crops like cotton and corn is secured from application of materials carrying potash. Especially is this so when this constituent is as high in price as it is at the present time. Even in the Piedmont section of the State there are certain types like the Iredell Loam in Mecklenburg and other counties that do not show any need at the present time for application of materials carrying phosphoric acid in available form, provided these soils are handled properly.

Most of the soils studied in the Coastal Plain section of the State show the main plant-food deficiencies to be nitrogen, potash, lime and phosphoric acid. On many of the black soils, high in nitrogen content, at present, crops show a marked increase in yield from the use of applications of nitrogen in available form. These results are not expected to continue after this type of soil has been brought into suitable condition for the growing of crops. These soils are well supplied potentially with nitrogen for the growing of large crops for a long time to come, but it is not in a form which the crops can use it. The phosphoric acid and potash in these soils, too, is contained in much larger quantities than has usually been the case with soils of this type found in other parts of the country. From a study of the soils of the State, it should be said that the incorporation of decaying organic matter is of prime importance at the present time. On most of the soils this material is so deficient that small applications of stable manure or the turning into the soil of a small growth of crops or crop residues will, in most cases, materially increase the yields.

It might be stated in this connection that in order to build up the productivity of the soils, it will be necessary, in practically all cases, for farmers to use leguminous crops in their rotations and to have a part of these at least to go back into the soil to increase the supply of organic matter and at the same time to add to the soils an increment of nitrogen which was taken from the unlimitable supply of the air by the plants. Although nitrogen is the main limiting constituent, as indicated above, with most Coastal Plain soils low in organic matter, yet, in most cases suitable carriers of phosphoric acid and lime have to be applied, if the best and most profitable system of agriculture is to be practiced by the farmers of this section of the State.

For some time we have been looking forward to the systematic publication of county soil reports. Since our last report, there has been prepared and issued reports of this nature for Mecklenburg, Gaston, Union and Cabarrus counties. In these reports is given definite information with reference to the agriculture, climate, and soils of the county. The recommendations given in the reports are based upon a scientific examination of the soils and upon carefully conducted field experiments on the leading kinds of soil found in the counties. It is believed that these reports will not only be of great value to agricultural workers who are devoting their time to the upbuilding of the agriculture of the different counties, but that it will be of great direct practical value to the farmers of the counties themselves.

The soil chemist with the hearty coöperation he has secured from the laboratory of the State Chemist, has analyzed samples of soil taken in soil survey work to the number of 106. The total number of soil samples taken since my last report to you, on which partial analyses have been made, have been 272.

POT CULTURE EXPERIMENTS.

Pot Culture experiments have been made to determine the relative availability of plant-food constituents when carried in various soil-forming minerals; the value of phosphoric acid contained in basic slag as compared with that carried in acid phosphate, finely ground phosphate rock, neutral sodium phosphate, and double superphosphate; and the immediate and ultimate needs of muck soils for the most profitable crop production.

Soil-Forming Minerals.—These experiments were begun in 1916 with the common soil-forming minerals that occur in North Carolina soils, and has been continued during the present year. Four crops, two of legumes and two of nonlegumes have been grown in the pots after applications of the different soil-forming materials had been carefully weighed and applied. The results thus far secured indicate rather wide differences in the availibility of potash, phosphoric acid and lime when supplied in these different minerals. A publication is now in progress of preparation covering the results that have been obtained in potash minerals of our soils.

Experiments With Basic Slags.—In these experiments two crops—Dwarf Essex Rape and German Millet—have been grown thus far. These have been harvested from the pots, weighed and analyzed. From the data thus obtained, it would appear that the phosphoric acid contained in basic slag can be assigned a value closely approximating that contained in available form in acid phosphate and double superphosphate with the types of soil studied.

Study of Muck Soils.—The pot and laboratory experiments which have been previously reported, have, too, been continued during the year. These experiments are designed primarily to determine the best methods that will have to be used in the treatment of this class of soils found to such large extent throughout certain parts of the eastern portion of the State. It has been found that lime, as previously reported, is still showing decidedly beneficial effects. In fact, without the addition of materials carrying this constiuent in both the field and pot experiments crops did not develop at all normally.

STUDIES ON THE CAUSE OF SOIL ACIDITY AND THE EFFECT OF CERTAIN FERTILIZING MATERIALS IN INCREASING ACIDITY.

With the hydrogen electrode apparatus, a number of typical soils of this and other states have been carefully examined. It has been rather conclusively demonstrated from the data thus far secured that true acids exist in a majority of the soils that have been studied. Samples from the "long time" fertilizer plots of the different Test Farms have been subjected to this line of investigation and the results of these studies indicate that:

1. Acid phosphate, when added to the soil in the quantities usually applied, does not increase the acidity of the soil.

2. Sulphate of ammonia, when applied as a fertilizing material to the soil, increases the acidity of the soil to a greater extent than does sulphate of potash.

3. Nitrate of soda, as might have been expected, has been found to reduce soil acidity.

The detailed results of these experiments with the deductions from the same have been put in shape for publication. An article embodying these data will shortly appear in the *Journal of Agricultural Research* of the U. S. Department of Agriculture.

WORK IN THE IMPROVEMENT OF FIELD CROPS.

During the year a large amount of work has been done on the Central and Branch Station Farms in the testing and improvement of varieties and strains of cotton, corn, oats, wheat, rye, soybeans and cowpeas. Long ago it was determined that work of this nature must, to a large extent, be carried on in the section or community in which the varieties are to be grown, if it is to be of the greatest value.

A detailed study of the inheritance and association of plant qualities in cotton has been made in the field. This work consists of a study of the economic qualities of the cotton plant, with special reference to its mode of inheritance and association in the plant.

During 1916 the progeny of seventy-two plants were grown and studied. From this progeny lot, 2,500 plants were carefully studied in the field in regard to their inheritance of height, of height to first branch, number of bolls, yield per plant, number of branches, number of nodes, size of boll, length of staple, per cent of lint, earliness of seed.

In this study attention has been paid to both the poor and good qualities. In ordinary selection one saves only the plants that have good qualities, consequently we know very little about the inheritance and behavior of the poor qualities. We know very little about their influence on yield, uniformity and quality of the crop. In these studies, an effort is being made to preserve both the poor and the good in order that we may better understand the inherited qualities found in an ordinary variety of cotton. The different qualities are being isolated and kept pure by self-fertilizing the plants and keeping the seed of each plant separately. During the two years of self-fertilization, the plants have not shown any evidence of lack of vigor.

During the course of the above studies, several distinct strains have been isolated from the King's Improved type, started with. For instance, strains like Cook, Cleveland, Culpepper, and Toole, have been isolated from this one variety. In fact, the strains isolated from this variety when grown side by side on uniform land show as great or greater differences than the varieties in the regular tests.

The work thus far has shown that the lack of uniformity and poor yield in ordinary varieties of cotton is due in part at least to mixtures of characters. This undesirable mixture of characters, such as short lint, poor yield, and lateness, is inherited, but may be eliminated by careful, persistent and intelligent field selection.

Cotton-Breeding Work on the Test Farms.

As a resut of carefully conducted cotton-breeding work, the Central Farm at Raleigh and the Iredell Farm have been stocked with pure cotton seed. This has been done with seed of strain No. 29, which was isolated from King's Improved at the Experiment Station farm in 1914. Good yielding strains also have been selected and multiplied at the Edgecombe and Pender Farms. At Edgecombe, the selections have been made from Mexican Big Boll variety. This variety is an early big boll type, which has one and one-eighth inch staple of a fairly uniform quality. The Pender Farm has been restocked with a good strain of Cleveland Big Boll cotton. Selections of individual plants have been made to further improve the strain for that section.

Experimental Corn-Breeding on Farms.—The seed corn of the Experiment Station, Buncombe, Iredell and Edgecombe Farms, is being improved in yield by selecting seed from individual plants and by ear-to-row testing. Each year the best strains are being turned over to the respective farms for seed planting purposes. By this means the quality of the corn on the different farms is gradually being improved.

Summary of Results of Tests of Varieties of Corn.

During the past season, corn variety studies were conducted at six of the experimental farms. These farms have been so located as to represent the more important soil types and climatic conditions of the State. Among the forty varieties tested, there were included a few of the best varieties from the neighboring states, several of the most promising varieties grown more or less generally throughout North Carolina, and a few varieties grown to considerable extent in certain restricted localities of the State. The results of such tests will furnish corn growers of the different sections with reliable information regarding the yielding power of the main varieties of corn grown in the different communities of the State. As a result of the tests, a few growers have already discarded old mixed varieties of seed, adopting seed of the better yielding and more uniform strains of varieties.

In addition to the comparison of yields of grain, the varieties have been studied with reference to their suitability for silage purposes. This work has shown that the best varieties of corn for silage are the ones that produce the largest quantity of digestible food per acre. Since the ears contain 63 per cent of digestible nutrients of the corn plant on an average, it is highly important that an ensilage corn produce a large

quantity of ears as well as stalks and leaves. The results of this work have been reported in detail in the February, 1917, Bulletin of the State Department of Agriculture.

The results of variety tests of corn conducted during the past three years have been compiled to determine which of the varieties tested have given the best average yields in different sections of the State. At the Buncombe farm, First Generation Cross No. 182, Latham's Double, Southern Beauty, and Weekley's Improved; at the Iredell farm, Southern Beauty, Jarvis Golden Prolific and Biggs' Seven-ear; and at the Central Station farm, Biggs' Seven-ear, First Generation Cross No. 182, and Southern Beauty; at the Granville farm, Biggs' Seven-ear, Batts' Four-ear, and Latham's Double, as a result of two trials; and at the Edgecombe farm, Biggs' Seven-ear, Latham's Double and Goodman's Prolific have yielded best. As a result of trials of two years at the Washington farm, Latham's Double, Horse-Tooth and Wanamaker's Prolific have thus far proven to be the largest yielders.

Best Soybeans for Different Sections.

During the past season, the Division of Agronomy has studied varieties of soybeans on seven of the Branch Station farms in order to determine the best yielding varieties for different sections of the State. At the mountain farm, the medium-early varieties, such as Haberlandt, Austin, Virginia and Wilson Black, have given the best results. Haberlandt and Austin have produced the highest yields of seed; and Virginia and Wilson Black have given the best results for hay. At the Piedmont farm, Mammoth Yellow, Tarheel Black and Virginia yielded most seed, and Tarheel Black, Virginia and Wilson Black the largest amounts of hay; while at the Edgecombe farm, Mammoth Yellow, Tarheel Black and Tokio produced the largest quantity of seed, and Virginia, and Wilson Black the most hay.

Best Cowpeas for Different Sections.

During the past season, fourteen varieties of cowpeas were grown in an experimental way in different sections of the State to determine their comparative yields of seed and hay, when grown under the different conditions. At seven of the test farms, the varieties have been compared with each other and with soybeans too for hay and seed production. When planted in rows the soybeans have produced more hay and seed than have the cowpeas, but when planted broadcast for hay, the cowpeas have generally outyielded the soybeans.

In the mountains, Taylor, Early Red, and Monetta; and in the Piedmont section, Groit, Black Unknown and Early Red varieties have been the best seed producers, while Clay, Monetta, and Iron have produced most hay. The Red Ripper, Black and Taylor have produced the largest quantity of seed, and Iron, Wonderful and Monetta the most hay in the Coastal Plain section of the State.

Results of Studies with Varieties of Small Grains.

In the small grain work, varieties of oats, wheat and of rye have been grown and compared at the Experiment Station farm and at four of the branch station farms. Results of these tests have furnished a list of the varieties which do best in the different sections of the State.

All of the small grain at the Mountain farm was destroyed by the floods last season. At the Piedmont farm, Purple Straw, Leap's Prolific, Fulcaster, and Fultz were the best yielders among the wheats, and were compared both for seed and hay yield. The Appler, Red Rust Proof and Fulghum varieties have shown up well at the Iredell farm in yield of both seed and hay. At the Experiment Station farm, the Red Rust Proof, Bancroft and Appler for seed, and the Virginia Turf, Red Appler and Fulghum for hay have produced most satisfactorily. At the Edgecombe farm, the Fulghum, Red Appler and Red Rust Proof varieties of oats ranked best in the production of both seed and hay. Among the varieties of oats compared at the Granville farm, the Appler, Red Rust Proof, and Fulghum produced the largest quantity of both seed and hay. At six of the branch stations, Abruzzi rye was compared with the Common Winter rye secured from different sources. In all cases, the Abruzzi rye has matured earlier and has yielded from 2 to 6 bushels of seed per acre more than the common varieties of rye tested. The Abruzzi rye, too, has given decidedly earlier and more material for pasturage during the early spring.

Results of Variety Tests of Peanuts.

Variety tests of peanuts have been made at the Edgecombe farm and the Cotton Valley farm in Edgecombe County. The results of these tests were secured too late to be included in our last report.

At this farm, the varieties that yielded the largest amount per acre were Virginia, North Carolina, Improved Spanish, Virginia Bunch, Small Spanish, Jumbo, and Valencia, in the order given. A study was made of the percentage of kernels to hulls of each of the different varieties. The percentage of kernels ranged from 66.8 per cent with Jumbo, to 78.0 per cent with Small Spanish. The percentage of pops ranged from 1.1 per cent with the Virginia Bunch to 8.8 per cent with the North Carolina variety.

PUBLICATIONS.

During the year the following publications have been prepared by the Division of Agronomy of the Experiment Station and published:

1. Tobacco Culture in North Carolina. Bulletin 237.
2. Harvesting Tobacco by Priming or Picking the Leaves as Compared with Cutting the Stalks, Bulletin 238.
3. Soybean Growing in North Carolina (reprint). Circular No. 31.
4. Soybean Products and Their Uses. Circular No. 34.
5. Velvet Beans; How to Grow and Use. Circular No. 35.

Before closing this report, I wish to express my deep gratitude to those associated with me in the Agronomy work. Whatever may have been accomplished by the Division is due largely to the interest and fidelity to duty of those who are associated with me in the work.

Respectfully submitted,

C. B. WILLIAMS,

Chief, Division of Agronomy.

REPORT OF THE DIVISION OF CHEMISTRY.

To the Director:

I take pleasure in submitting herewith the report of the Division for the year ending June 30, 1917. The greater part of the work for the year is embodied in five articles containing the results of investigations with cotton-seed meal. The first named article appeared in the October number of the *Journal of Biological Chemistry;* the second in the November number of the same journal; the third has been accepted for publication in the *Journal of Agricultural Research.* A summary of the principal conclusions is as follows:

METHODS OF APPROXIMATING THE RELATIVE TOXICITY OF COTTON-SEED PRODUCTS.

It has been found that the raw cotton-seed kernels are highly toxic to animals. After cooking with moist heat processes and expressing the oil the meal is very much less toxic than the original kernels. The experiments indicate that gossypol is the toxic principle of the kernels and that in preparing the meal this principle is extracted to some extent by the oil and is changed to some extent to a less toxic substance which we have designated as "D" gossypol.

The presence of the unchanged gossypol in the meal may be indicated by the red area produced when concentrated sulphuric acid is added to a part of the meal sprinkled on a glass slide and observed through a microscope (low power).

The quantity of unchanged gossypol may be determined by treating the meal with ethyl ether and precipitating with aniline. This compound of aniline was first prepared in this laboratory.

IRON AS AN ANTIDOTE TO COTTON-SEED MEAL INJURY.

In previous experiments by this division rabbits were fed on cotton-seed meal 106 days when ferric ammonium citrate was added to the diet.

More recently the effect of adding iron in the form of ferrous sulphate and ferric chloride to cotton-seed meal in feeding swine was tried. There were four feeding experiments with pigs and these have shown that iron salts exert a decidedly beneficial action in preventing cotton-seed meal injury. Much larger quantities of meal are consumed, deaths have been postponed or averted and better gains have been made when an iron salt is added to the feed.

By thus controlling to some extent the toxic factor, the conclusion seems justified that cotton-seed meal injury is not due to a lack of vitamines or to deficiencies in calcium, sodium or chlorine, which ash analyses might lead one to suspect as the limiting factors in a diet of cotton-seed meal and corn.

Some of these experiments were conducted under favorable conditions for growth and others under unfavorable conditions. Under favorable conditions the beneficial effects of iron salts were more marked and under less favorable conditions they were not so marked. In these experiments there were some animals that yielded to the toxic effects of the meal notwithstanding the presence of iron salts.

Some experiments were also conducted in which wood ashes were placed in troughs easily accessible to pigs receiving cotton-seed meal. The ashes did not appear to exercise any effect in the way of overcoming the toxicity of meal, but as the lot receiving ashes made better gains it is possible that ashes improved the inorganic part of the diet.

GOSSYPOL, THE TOXIC SUBSTANCE IN COTTON SEED.

Since the publication in 1915 of the experiments which led us to advance the theory that the toxicity of cotton seed is due to the presence of gossypol, other explanations have been offered. One, that the injury is similar to beriberi and is caused by deficiency in diets, insufficient minerals or possibly inadequate amounts of fat soluble growth-promoting substances.

It has been determined that meal is much less toxic than kernels as stated above. The condition of cooking gives great variation in the toxicity of the meal. Notwithstanding the reduction in toxicity due to cooking, however, raw seed after extraction with ethyl ether is not only less toxic to pigs than cooked meal but it does not seem to be toxic at all. The main substances extracted by ether are gossypol and oil and gossypol is indicated by this fact as the toxic principle of the seed. We have also fed the extracted gossypol to pigs and have found it to be toxic.

We have found, however, that a diet of cotton-seed meal and corn meal has nutritive limitations and may under restricted conditions of life lead to failure in the case of pigs. Such failure, however, is a phenomenon entirely distinct from cotton-seed meal poisoning.

Outdoor exercise, access to forage and soil and improved diets tend to postpone or avert cotton-seed meal poisoning of swine.

CONTRIBUTION TO THE CHEMISTRY OF GOSSYPOL.

In 1899 Marchlewski isolated a crystalline product from the "foots" of cotton-seed oil by means of a tedious process of purification. He named the crystalline substance gossypol from gossyp(ium-phen)ol. This substance in an impure state had been noted by others previously.

Our experiments indicate that Marchlewski's "gossypol" was a substance containing one molecule of acetic acid in loose combinations with the phenolic body. This compound may be called gossypol acetate and the phenolic body itself gossypol.

Gossypol appears to be a constituent of the cotton plant only. It occurs in peculiar glands called "Gland dots," which are present in all

parts of the plant except the woody tissue. They are readily visible to the naked eye. The glands in the root-bark, leaf, petals and boll, as well as those of the seed, give, with sulphuric acid, a characteristic red color from which it is inferred that gossypol exists in all these. Unextracted kernels contain about 0.6 per cent gossypol, ethyl ether extract about 1.8 per cent, and kernels after extracting by petroleum ether about 0.9 per cent.

We have found it very much simpler to isolate gossypol from the seed than from the foots as Marchlewski did. Gossypol may be dissolved in eythl ether and precipitated with acetic acid, petroleum ether or aniline, details of which methods are given in the paper referred to.

Our experiments indicate that gossypol has a molecular weight of 530 or 532 and an empirical formula $C_{30}H_{28}O_9$ or $C_{30}H_{30}O_9$.

The different methods by which we were led to this conclusion are contained in the paper.

Three substance resembling gossypol, more or less, have been isolated. Two of these are yellow. The third appears to be without color. We have designated as "D" gossypol the substance formed from gossypol in cooking the seed; "B" gossypol as the substance formed by heating gossypol in the air to its decomposition point; and as "C" gossypol the colorless substance which is formed by fusing gossypol with alkalis at a high temperature.

Gossypol is oxidized in alkaline solution, a blue substance being formed first which subsequently disappears.

COMPARATIVE TOXICITY OF COTTON SEED PRODUCTS.

Various cotton seed products including raw kernels, ether extracted kernels, gossypol and several meals have been fed to rats, rabbits, poultry and swine.

Raw kernels and gossypol have been found highly toxic to all these animals. The toxicity is very much reduced by cooking under oil mill conditions but is still harmful to rabbits and swine. The toxic effects are very much less marked upon rats and fowls.

Milk powder appears to overcome, for rats, any toxic substance in the meal.

Rabbits are more susceptible to cotton-seed meal poisoning than rats.

Aside from apparently diminshed egg production excessive amounts of cotton-seed meal have not appeared to be injurious to hens. There is some evidence that unchanged gossypol in the diet may cause a peculiar discoloration of the egg yolk.

Pigs were fed peanut meal, soybean meal, cotton-seed meal and ether extracted kernels and the latter were found to give the best results.

The time and temperature of cooking have an effect upon the toxicity. Addition of other substances as meat scrap, calcium lactate, sodium

chloride and butter fat or 10 per cent skim milk powder have exerted a beneficial effect. Green feed, open air and moderate exercise have also been helpful. We have not been able to find any feeding material which is able to overcome for swine cotton-seed meal injury. We have, however, overcome the injury by extracting gossypol from raw kernels.

Our former conclusion is thereby confirmed that gossypol is a toxic principle of cotton seed.

SOIL BACTERIOLOGY.

During the past year studies in nitrification and ammonification have been mainly with solutions. We have endeavored to study the effects of the presence of certain constituents in nutrient solutions and the effect of the concentration of various constituents.

We have usually found that in preparing nitrification nutrient solutions that precipitation takes place. Micro-chemical examination indicated that for the most part the precipitates were ferric phosphates, but in some solutions secondary calcium phosphate appeared to form also. The conditions appeared to be favorable for the solution of the precipitate of magnesium ammonium phosphate but we found no indication of this substance in the precipitate formed in any case.

When these solutions were filtered in order to remove the precipitate nitrification was materially retarded, indicating that the micro-organisms are able to utilize precipitates. The presence of calcium carbonate was favorable to nitrification.

Calcium carbonate appears to liberate ammonia from ammonium sulphate. A large loss of nitrogen occurred in all solutions. As this loss is usually greater in an uninoculated solution than an inoculated one, the phenomenon would appear to be chemical rather than biological. Dipotassium phosphate and ferric sulphate appear to give better results than monopotassium phosphate and ferrous sulphate, possibly on account of their lesser degree of acidity. Magnesium appears to give better results in the form of sulphate than in the form of chloride.

These conclusions are stated with some degree of hesitancy as the results are not uniform and variations occur, the reasons for which are unknown to us. We also studied the effect of the container and found that rectilinear bottles resting on their largest side during incubation gave very much better results than Erlenmeyer flasks, leading us during the latter part of our work to abandon the use of Erlenmeyer flasks for incubation purposes.

Changes in the staff of this Division have involved the resignation of Messrs. F. E. Carruth and L. B. Johnston, who resigned to accept positions elsewhere.

The Chemist to the Station has been elected, during the year, President of the North Carolina Academy of Science.

Very truly yours,

W. A. WITHERS,
Chemist, Experiment Station.

REPORT OF THE ANIMAL INDUSTRY DIVISION.

To the Director:

In response to your request, I am herewith handing you a report of the experimental work of the members of the Animal Industry Division for the year ending June 30, 1917.

SWINE.

The work with feeding and breeding hogs is being conducted at the Central Station Farm at Raleigh, the Iredell Branch Station Farm at Statesville, the Edgecombe Branch Station Farm at Rocky Mount, and at the Pender Branch Station Farm at Willard. While the work undertaken has progressed satisfactorily, still many projects have had to be neglected on account of the small appropriation made to support the test farms. It is hoped that some funds can be secured for the test farms as it is not only necessary to carry on the lines of work we have under way more completely and comprehensively, but it is also necessary to inaugurate new and additional work. No live stock work at all, for instance, is being done at the Buncombe Branch Station Farm and the only reason that can be given for this neglect is that the test farm appropriations are not sufficiently large to warrant the undertaking of new live stock projects.

Value of Soybean Pastures for Hogs.

(Central Station Farm.)

I judge, both from correspondence and from personal interviews with farmers, that it is very difficult for many of them to learn that it is absolutely impossible to make money with any kind of live stock unless pastures of various kinds are used as a basis. All of the live stock men are continually besieged with the question as to how money is to be made with live stock without pastures. For this reason the most of our investigational work swings around the utilization of pastures.

One of the best pastures, and one that can be used practically anywhere in the State, is soybeans. We have been making a special effort the last year to emphasize its feeding value. In this experiment the number of pigs on hand was divided into two lots. The first lot of pigs was enclosed in a small lot and fed upon a ration made up of two-thirds corn plus one-third wheat shorts. The second lot of pigs was given a ration made up of soybean pasture and no grain at all. The experiment lasted from October 9, 1916, to January 9, 1917. The first thing of interest to note in this experiment is that hogs running upon soybean pasture gained just twice as rapidly as did those which were enclosed in the lot and fed all the corn and shorts they would consume. When

this experiment was under way shelled corn was valued at $45 a ton, wheat shorts at $38 a ton, and soybean pasture at $10 an acre. When these values were placed upon the feed, it cost $13.24 to produce each 100 pounds of increase in live weight in the dry lot and only $5.50 to produce an equivalent increase in live weight in the soybean-pasture lot. The soybean pasture was not exceptionally good. In fact, it was far below the average of the yield usually secured by farmers in the coastal section but even at this, 200 pounds of pork were produced to each acre.

Value of Soybean Pasture for Feeding Dry Brood Sows.

(Central Station Farm.)

The usual permanent pasture season ends with the coming of the frosts and with the ending of the summer pasture comes a period of expensive feeding if the farmer has not changed his grazing system and provided for something for fall and winter. In fact, the months of October, November, and December constitute a discouraging period for farmers who produce hogs. One of our lines of work is to work out a pasture system bridging over these months, and in this work we have found that soybean pastures are exceedingly valuable. In the spring of 1916 we planted 2.6 acres of soybeans with the object of using the area for feeding brood sows during the fall and early winter. The area used was an old abandoned cotton patch, where the soil had been exhausted some years previously and was over-run with a rather dense growth of Bermuda. The ground was broken in the usual way and the beans planted in rows about three feet apart. As the soil was poor, the yield of beans was only 15 bushels to the acre. On October 9, when the period of usefulness of the Bermuda pasture was passed, eight sows were turned into the soybean field of 2.6 acres. At the beginning the sows averaged 227 pounds in weight and at the close, 49 days later, or November 29, they averaged 244 pounds in weight. Not a pound of grain was fed. During this time the sows ate 40.2 bushels of soybeans, but it certainly is not fair to charge the beans against the sows at the market price, as no expense was entailed in harvesting and preparing them for the market. The sows harvested them without expense. If the eight sows had been fed upon corn alone during this time and made the gains they did make upon pasture, they would have eaten not less than one bushel of shelled corn a day, or 49 bushels for the whole period. As a matter of fact, the soybean-pasture ration, when everything is considered, certainly did not cost over $30 for the whole time.

Just at the present time this test is being duplicated and the results, as far as we have gone, are as satisfactory as the previous one.

Feeding Cotton-seed Meal to Hogs.

(Central Station Farm.)

The cotton-seed meal work is being carried on in coöperation with the Chemistry Division. On account of the fact that this piece of work must be done in an extremely painstaking way and is also very expensive, it is conducted at the Central Test Farm at Raleigh. In this work we know that the gains must be necessarily small and expensive and that heavy losses are to be encountered, because cotton-seed meal has a poison in it and many of our animals are killed before the experiment continues very far. During the past year seven lots of hogs were used in this experiment but due to the scarcity of hogs, only three were used in each lot. The object of this experiment was to determine if the length of time that cotton-seed meal was cooked, during the process of making, had any effect upon the toxicity. Also to determine if other materials could be fed with cotton-seed meal to correct the ill effects of the cotton-seed meal. In addition to these two problems with cotton-seed meal, two check lots were used to determine the feeding value of soybean meal and peanut meal, as compared with cotton-seed meal. The rations used are as follows: Lot 1 was fed a ration of 25 per cent cotton-seed meal (cooked two hours), 65 per cent of cracked corn, and 10 per cent of wheat bran; lot 2 was fed 25 per cent of cotton-seed meal (cooked 24 minutes), 65 per cent of cracked corn, and 10 per cent of wheat bran; lot 3 was fed 25 per cent of soybean meal, 65 per cent of cracked corn, and 10 per cent of wheat bran; lot 4 was fed 25 per cent of peanut meal, 65 per cent of cracked corn, and 10 per cent of wheat bran; lot 3 was fed 25 per cent of soybean meal, 65 per cent of cracked corn, and 10 per cent of wheat bran; lot 4 was fed 25 per cent of peanut meal, 65 per cent of cracked corn, and 10 per cent of wheat bran; lot 5 was fed 25 per cent of ether extracted cotton-seed kernels, 65 per cent of cracked corn, and 10 per cent of wheat bran; lot 6 was fed 30 per cent of cotton-seed meal (cooked two hours), 42 per cent of cracked corn, 20 per cent of wheat bran, 3 per cent of tankage, and 5 per cent of butter plus 800 grams of a salt mixture composed of calcium lactate 350 grams, calcium phosphate 320 grams, common salt 100 grams, iron and ammonium citrate 30 grams, to each 100 pounds of grain; lot 7 was fed 30 per cent of cotton-seed meal (cooked two hours), 40 per cent of cracked corn, 20 per cent of bran, and 10 per cent of skimmed milk solids.

No definite results have been determined from this experiment and it will be continued on through this year.

The Amount of Corn Which Should be Fed in Conjunction with Soybean Pasture.

(Edgecombe Branch Station Farm.)

Whenever soybean pastures or any other kind of pastures are discussed as feeds for hogs the farmer is sure to ask how much corn should be fed in conjunction with pasture. This question, of course, is an extremely practical and important one. To answer the question and at the same time determine the effect of soybean pastures upon the bodies of swine, a series of experiments has been outlined and is being carried through upon the Edgecombe Branch Station Farm.

During the summer of 1916 a rather large area of soybeans was grown. This area was used in this experiment. On September 19, 1916, 32 pigs were divided into three lots. The first lot of pigs was fed in a dry lot upon a ration made up of two-thirds corn plus one-third wheat shorts; the second lot of pigs was grazed upon soybean pasture and in addition given a half ration of corn and wheat shorts; the third lot of pigs was simply given a ration of soybean pasture. The pigs at the beginning were all young and small, averaging 63 pounds in weight. None of them, therefore, made large average daily gains during the soybean period of 105 days. The gains made, however, were interesting. The pigs in the first lot (the dry lot) made an average daily gain of .36 of a pound; the pigs in the second lot (pasture plus grain) made an average daily gain of .49 of a pound; the pigs in the third lot (soybean pasture alone) made an average daily gain of .14 of a pound. As far as gains are concerned, therefore, it paid to supplement the pasture with a half ration of grain. What about the cost? In the first lot (dry lot), it cost $17.89 to make each 100 pounds of increase in live weight; in the second lot (soybean pasture plus corn), it cost $9.37 to make an equal increase in live weight; and in the third lot (soybean pasture alone), it cost $19.20 to make each 100 pounds of increase in live weight. The above expenses are based upon corn at $1 a bushel, wheat shorts at $38 a ton, and soybean pasture at $10 an acre. This single experiment indicates, therefore, that some grain should be fed in conjunction with soybean pasture. The work, however, is being duplicated this year with an increased number of hogs. Peanut pastures as well as soybean pastures, also constitute a part of the work now under way.

Value of Soybean Pasture in Conjunction with Corn.

(Cotton Valley Farm.)

To gain the confidence of some farmers, it is often necessary to project the results of our investigational work upon practical farms and in conjunction with practical farmers. Sometimes farmers feel that they cannot afford to do what the authorities of the State Agricultural Institistitutions recommend but when the results of our investigational work

are carried on on the farm of some practical farmer and duplicated in a large way, we have no difficulty in convincing the average farmer that our teachings are correct.

To meet just such conditions as these, we have made arrangements with the owners of the Cotton Valley Farm, Messrs. Holderness and Shook, Tarboro, N. C., to use their farms and capital in demonstrating that our test farm teachings are correct. We are, in short, using their farms to demonstrate practical, expensive, and scientific investigations on the test farms.

Last year a very large area of soybeans was grown upon the Cotton Valley Farm. On September 26, 1916, 185 pigs, averaging about 50 pounds in weight, were turned on to a large field of soybeans and fed corn in conjunction. The supply of soybeans was exhausted December 29, 1916. During this time the pigs made satisfactory gains and economical gains. When corn is valued at $1 a bushel and soybean pasture at $8 an acre (which is the value placed upon the feeds by Mr. Shook, the manager), it cost $6.29 to make each 100 pounds of increase in live weight. These results are somewhat better than those secured upon the Edgecombe Test Farm. The pigs at the end of the soybean period were not, of course, ready for the market as they were soft. At this time they were placed in a dry lot and hardened for the market, but this phase of the work is reported under another heading.

The experiments on the Cotton Valley Farm are also being duplicated this fall, the object being to determine the amount and cost of pork that can be made from each acre of peanuts and also to determine the amount of pork that can be made from the gleanings after the peanuts have been harvested.

Relative Value of Soybean and Peanut Pastures.

(Pender Branch Station Farm.)

Those who have used both soybean and peanut pastures know that both of them are very valuable as feed for hogs. Many farmers, however, are asking which is the more valuable of the two. To answer the question a series of experiments is being carried through at the Pender Branch Station Farm. The first year's results were reported last year. Members of the Board who have visited the Pender Branch Station Farm know that two areas have been set aside for this work. Each year soybeans are grown upon one area and peanuts upon the other. Last year the soybeans were ready to be grazed before the peanuts so the hogs were divided into three lots, two of them being carried in small pens until the peanuts were ready, while the third one was started immediately upon the soybean pasture. The first lot of pigs was fed a ration made up of two-thirds corn plus one-third wheat shorts; the second lot of pigs was fed just half as much corn and shorts plus soybean pasture; the third lot of pigs was fed peanut pasture in place of

soybean pasture. The experiment began October 5, 1916, and closed 84 days later. During this time the pigs in the first lot (grain only), gained daily .35 of a pound; the pigs in the second lot (soybean pasture), gained .48 of a pound; while the pigs in the third lot (peanut pasture), gained 1.41 pounds daily. When shelled corn is valued at $40 a ton, wheat shorts at $36 a ton, and soybean and peanut pastures at $10 an acre, it cost $22.68 to make 100 pounds of increase in the dry lot, $10.77 in the soybean-pasture lot, and $5.90 in the peanut-pasture lot. It is seen, therefore, that both pastures were valuable but that the peanut pasture was more valuable than the soybean pasture. Peanut pasture has another advantage as indicated by the gains made daily. From the standpoint of the amount of pork made on each acre, there was practically no difference in the cost. The pork was made very much more rapidly on peanuts than on soybeans. This, of course, is a point in favor of peanuts.

Cost of Raising Pigs to the Weaning Age.

(Cotton Valley Farm, Iredell, Edgecombe and Pender Branch Station Farms.)

The average farmer finds more difficulties facing him during the suckling period of the pigs' lives than at any other time. Very little study has been given to this period of the pig's life and really no valuable information has been collected as to just what it costs to raise a pig up to weaning time and as to the best method of handling and feeding this time. Upon the three test farms indicated above and also at the Central Station Farm at Raleigh, close studies are being made and accurate data collected as to just what it costs to raise a pig. In my last report I called your attention to the fact that this work was under way. While it is not finished by any means, some interesting facts are coming to the surface. So far, we have accurate information on the cost of raising pigs from 45 sows. Upon the Iredell Branch Station Farm complete records have been secured on 13 litters of pigs and it has cost $2.24 to get each pig to the weaning time. At the Pender Branch Station Farm 11 litters of pigs have been studied and it cost $3.10 per pig; at the Edgecombe Branch Station Farm 12 litters have been studied and it cost $2.04 per pig; at the Cotton Valley Farm 24 litters of pigs have been under observation and it cost $3.18 per pig. The cost of keeping the mother is, of course, included in the above estimates.

Curing Meat on the Farm.

(Pender Branch Station Farm.)

Just at the present time the question of curing meat on the farm is a vital one. Fortunately for us, we are in position to give the people some definite information as to the best method of curing and keeping

meats. This work was inaugurated at the Pender Branch Station Farm last year and plans were made to supplement it upon the Central Station Farm. Eighteen hogs were used in the experiment. Nine of them were sold immediately after killing and nine were cured at the farm. As the prices ruled last winter $66.92 more were received from the meat that was cured on the farm than for that which was sold fresh. This, of course, includes the returns from the lard, heads, ribs, trimmings, etc., which were sold fresh. Two different methods were used in curing the meat. One-half was put down in dry salt and the other half in a brine mixture, made of 12 pounds of salt, 3 pounds of brown sugar, 3 ounces of saltpetre, and 6 gallons of water to each 100 pounds of meat. The curing period lasted 27 days and during this time the meat in the brine shrank in weight 3.4 per cent, while that in the dry salt shrank 7.5 per cent. After the meat was taken out of the curing materials, one-half was cured with liquid or prepared smoke and the other half was cured in the old fashion way, with hickory smoke. The smoking period lasted 27 days. At the end of this time all of the meat was wrapped in paper and cheese cloth and allowed to hang in the smokehouse for 34 days and then sold. When the meat was unwrapped to be sold it was found that the fat and lean had separated to some extent on the meat that was smoked with liquid smoke, while that treated with hickory smoke had not. The meat which had been treated with hickory smoke also had a better appearance and sold much more readily. There was no noticeable difference, however, in the internal appearance of the meat or in the taste after it was cooked.

Is it Profitable to Harden the Bodies of Hogs After They Have Been Rendered Soft as a Result of Eating Soft-Producing Feeds?

(Pender and Edgecombe Branch Station Farms and Cotton Valley Farm.)

Peanut and soybean pastures are probably the cheapest feeds we have for hogs. Unfortunately, both of these pastures make soft-bodied animals and soft-bodied animals sell at a discount upon the open markets. The tendency, however, is for the farmer to sell a hog or try to sell him just as soon as these cheap feeds are gone and it is a very difficult thing to do to show him that the hardening period is in itself a profitable period. The average farmer is inclined to think that the grain fed during the hardening period is practically lost. One of our main lines of work upon the different farms is to determine just what it does cost to finish hogs for short periods of time after they have been grazing upon peanuts and soybeans. On account of the fact that this project is being investigated at three places very much material bearing upon this point is now accumulated. In a general way the results show that it does pay to harden the bodies even though the buyer fails to respond with increased prices. When, however, the purchaser

does pay extra, which is usually the case, for hard-bodied hogs, the owner of the animal profits very greatly, provided, the finishing period is not continued over 35 days. The following table gives the results of one of our completest experiments. This work was done upon the Cotton Valley Farm. It should be noted, however, that the hardening period was only 26 days, and this was not a sufficient length of time to bring soft-bodied hogs back to the proper degree of firmness.

Lot No.	*No. Hogs.*	*Ration.*	*No. Days.*	*Feed to make 100% gain.*	*Cost to make 100% gain.*
1	20	Shelled corn	26	7.1 bu.	$12.40
2	20	Shelled corn 9-10	26	6.5 bu.	13.80
		Cotton-seed meal 1-10		40 lbs.	
3	20	Shelled corn 7-8	26	6.8 bu.	14.70
		Cotton-seed meal 1-8		55 lbs.	
4	20	Shelled corn 4-5	26	8.5 bu.	19.38
		Cotton-seed meal 1-5		119 lbs.	
5	20	Shelled corn 3-4	26	6.0 bu.	14.24
		Cotton-seed meal 1-4		112 lbs.	
6	20	Cracked corn 2-3	26	5.6 bu.	14.32
		Cotton-seed meal 1-3		156 lbs.	
7	20	Cracked corn 3-4	26	4.7 bu.	11.12
		Sotton-seed meal 1-4		86 lbs.	
8	20	Ear corn 9-10	26	9.8 bu.	20.82
		Cotton-seed meal 1-10		61 lbs.	
9	20	Shelled corn 9-10	26	6.3 bu.	14.16
		Tankage 1-10		39 lbs.	

In the above table corn is valued at $2.00 a bushel, cotton-seed meal at $40 a ton, and tankage at $80 a ton. The last column in the table shows that gains are very expensively made when grains are very high in price, but the price of hogs at the present time almost, if not quite, corresponds. Quoting from the Jacksonville, Florida, quotations of August 14, 1917, 180- to 300-pound good hogs are selling for $14.75 to $16; 150- to 200-pounds hogs from $14 to $15.25; 125- to 150-pound hogs from $13.50 to $14.25; pigs from 65 to 120 pounds from $10.50 to $14. Even with corn at $2.00 a bushel, the most economical lots were finished profitably, lot 7 being notable in being extremely economical when compared with other lots. In lot 7 cracked corn and cotton-seed meal were employed and the expense of making each 100 pounds of gain was $11.12. In other words, each pound of increase in weight during the finishing period was added profitably while at the same time the selling price of the whole body was advanced materially. Many farmers are under the impression that satisfactory daily gains are not made when hogs are taken from peanut fields and enclosed in dry lots and continued on dry feeds. This is a mistaken idea, however. The hogs in the above experiment gained daily 1.7 pounds, 1.8 pounds, 1.6 pounds, 1.5 pounds, 1.4 pounds, 1.9 pounds, 1.1 pounds, 1.9 pounds in lots 1, 2, 3, 4, 5, 6, 7, 8, 9, respectively.

The Cheapening Effect of Peanut Pasture, Soybean Pasture, and Mast Upon the Bodies of Hogs.

As you know, the workers of the Animal Industry Division are devoting much time to determining just what effect peanut pasture, soybean pasture and other feeds have upon the bodies of swine. It is necessary for us to do this because it is such a vast economical Southern problem. Some of the feeds of the South, notably peanuts, soybeans, and mast, produce soft-bodied hogs. When these hogs are placed on the market they are discriminated against from one to two cents a pound which is, of course, an enormous financial loss to the South. Just how this loss can be overcome is one of our biggest problems and it is one which we are studying in our laboratories and upon our test farms. During the past year, we secured samples from all of the hogs fed in the experiments heretofore reported. These samples have been sent to our chemical laboratory and thoroughly analyzed to determine the effects of feeds upon the bodies of the hogs fed.

We have determined, I might say conclusively, that soybean meal and peanut meal do not make soft-bodied hogs notwithstanding the fact that packers have often discriminated against hogs fed upon these meals.

Last winter and spring one experiment was carried through at the Edgecombe Test Farm to determine just what effect peanut meal and damaged peanuts have upon the bodies of hogs. Thirty-three hogs, which were raised upon the Edgecombe Test Farm, were employed in the test. The experiment was inaugurated January 26, 1916, and closed June 26, 1916, when the hogs were shipped to the Baltimore market, sold, samples of fat obtained and returned to our North Carolina laboratories for analyses.

At the beginning of the test three hogs were slaughtered, fat (kidney fat), samples secured, and the melting point determined. It was learned that the average melting point of this fat was 38.5 degrees. The pigs were young, which no doubt partially accounts for the low-melting point. It should be recalled that the fat secured from hogs which have been fattened upon corn alone melts at an average temperature of 42 to 43 degrees, and that lard which has this melting point is entirely satisfactory. The pigs used in this test were, therefore, somewhat soft at the beginning.

The 30 remaining pigs were then divided into three equal groups and enclosed in small bare lots. The pigs in lot 1 were fed the whole time from January 26 to June 26 on a ration of two-thirds corn plus one-third wheat shorts; those in lot 2 on a ration of two-thirds corn plus one-third damaged peanuts; and those in lot 3 on a ration made up of two-thirds corn and one-third peanut meal.

When these hogs were killed it was found that the first and last rations did not materially affect the firmness of the bodies of the hogs,

but the second ration, where damaged peanuts were used, had a tendency to produce soft-bodied animals. The results can be shown in a short table:

Lot No.	*Ration.*	*Melting Point.*
At beginning	Taken from run on farm	38.5 degrees
1	Corn 2-3	
	Wheat shorts 1-3	39.1
2	Corn 2-3	
	Damaged peanuts	36.0
3	Corn 2-3	
	Peanut meal 1-3	38.3

The people who bought these hogs had no criticism to make, although all of the hogs were really somewhat soft, even those that were fattened on corn and wheat shorts, when measured by the corn standard. Many buyers would have criticised the bodies of the hogs which were fattened upon corn and waste peanuts, as the melting point was as low as 36 degrees. These hogs all started out somewhat soft and remained somewhat soft to the end, although the damaged-peanut-fed hogs were the softest.

A similar experiment was repeated at the Central Station Farm at Raleigh. The second test was begun January 28, 1916, and closed June 16, 1916, 31 hogs being employed. At the beginning of this test three average hogs were slaughtered and the average melting point of the fat was found to be 41.1 degrees, being almost as firm as fat taken from hogs fattened on a ration of corn alone. The remaining 28 pigs were then divided into three equal lots and placed in small pens, free from grass. The pigs in lot 1 were given a ration made up of two-thirds cracked corn plus one-third wheat shorts; those in lot 2 were fed a ration of two-thirds cracked corn plus one-third soybean meal; those in lot 3 were given a ration of two-thirds cracked corn plus one-third peanut meal. When these hogs were sold and killed, samples of kidney fat were taken to the laboratories for analyses. The final results were as follows:

Lot No.	*Ration.*	*Melting Point.*
At beginning	Grain mixture	41.1 degrees
1	Corn 2-3	
	Wheat shorts 1-3	41.9
2	Corn 2-3	
	Soybean meal 1-3	42.0
3	Corn 2-3	
	Peanut meal 1-3	42.1

The bodies of these pigs were firm when the test was inaugurated and continued to become firmer as the experiment continued. At the end the softest hogs were found in lot 1 where corn and wheat shorts were fed—

the firmest bodies being found in the lots where soybean meal and peanut meal were employed. The bodies were all satisfactory. It may, therefore, be said in conclusion that the results so far secured seem to show that soybean meal and peanut meal do not produce soft-bodied hogs.

Upon the Cotton Valley Farm, where large numbers of hogs were used, we have found that the bodies of soft hogs can be brought back to a corn standard in something less than 48 days. The kidney fat taken from the bodies of hogs which have been fattened upon corn alone have a melting point of about 43 degrees. This is satisfactory to the packers or any one else. Upon the Cotton Valley Farm some hogs were fattened upon soybean pastures. At the end of the soybean-pasture-period they had a melting point of 28.6 degrees, or the lard was practically oil. Forty of these hogs were put up in a dry lot and finished for 48 days on a ration of corn, cotton-seed meal, and peanut meal and at the end of this time the melting point was raised to 44.2 degrees. This was somewhat firmer than we expect to secure when corn is fed alone. Forty-eight days is, of course, too long a period to be economical. Our problem is, therefore, to shorten the period in some way.

Upon the Edgecombe Branch Station Farm some hogs which were fattened upon soybean pastures came off with a melting point of 31.5 degrees. The markets would discriminate against them probably 1½c a pound. These hogs were then put up in a dry lot and fed 36 days on corn and shorts, when they had a melting point of 39.2 degrees. The bodies even then were somewhat soft and would have been discriminated against upon an open market.

This line of investigational work is yielding some of our most satisfactory and profitable results. It is hoped that we will be in position before very long to make definite recommendations as to just how long it will take to harden soft-bodied hogs and just what the best feeds are. We, no doubt, know even now the best combinations of feeds, although all combinations have not as yet been tried out. So far, however, we have found nothing equal or even comparable to cotton-seed meal for hardening soft hogs.

BEEF CATTLE.

The investigational work, under the direction of Mr. Curtis, has been done at the Central Station Farm at Raleigh, upon the farm of T. L. Gwyn, of Haywood County, and in coöperation with Holderness and Shook, of Tarboro, upon the Iredell Branch Station Farm, and upon the Edgecombe Branch Station Farm

Trembles or Milk Sickness.

(Central Station Farm.)

People who live in the mountains know that there is an extremely dangerous disease in that part of the State which when occurring in

animals is called Trembles, and when occurring in humans is called Milk Sickness. The cause of this disease has been a mystery for over one hundred years and during this time the losses among live stock have been enormous and many humans have died as a result of drinking milk from animals having the disease.

In July, 1916, the Animal Industry Division, under the direction of Mr. Curtis, inaugurated an investigation to determine, if possible, the cause of this mysterious disease. Later on Dr. Wolf, of the Botany Division, was brought into the investigation and Dr. Kaupp, of the Animal Industry Division. Sheep were used as a basis for the study on account of the fact that cattle are too expensive. Some time ago a physician of the North, Mosely, claimed that White Snakeroot, locally known in North Carolina as Richweed, was the cause of Trembles in animals. His claims, however, were given no credence by investigators until the matter was taken up by this Division. The experiment is carried on by gathering the green weed in Clay County and shipping it to Raleigh, where it is fed to animals. During the months of June, July, August, September, and October, 1916, fifteen cases of Trembles in sheep were developed by feeding them various amounts of Richweed. Fourteen of these resulted fatally and one recovered. Death resulted in from five to twenty-five days following the beginning of the feeding of the weed. Considerable variation existed among the ewes, some succumbing to the disease much more readily than others. It is very often claimed that salt and soda have curative properties. Both of these chemicals were tried during the first year's work but without apparent antidotal effect.

During the summer just past, the work was continued further. Six ewes were fed on Richweed and the lambs allowed to suckle to determine whether the Trembles is transmitted through the milk. Two typical cases of Trembles developed in the lambs. Six dry ewes were also fed on Richweed to corroborate the work of last year. All of the ewes were lost with typical cases of Trembles as were also the ewes in the first experiment when the milk flow ceased. Mr. Curtis and Dr. Wolf have extracted the juice from the plants and found it to be exceptionally poisonous and it also produced typical cases of Trembles. Dr. Kaupp has studied the pathological phases in all of the animals under investigation. Chemical analysis has also been started under the direction of Mr. McCarty for the purpose of eliminating the specific poisonous principle.

It is difficult, of course, to get the farmers to accept our results. To establish confidence, three field experiments have been started in Clay County with Mr. M. R. Penland, with Mr. E. S. Millsaps, Jr., in charge, one at the Sheep Experimental Farm in Mitchell County, and one at the farm of Mr. T. L. Gwyn of Haywood County.

Vast good is sure to flow from the results of this investigation, as it seems now that the disease can be controlled easily by simply destroying the Richweed.

The Effect of the Continued Feeding of Cotton-Seed Meal to Breeding Animals.

(Central Station Farm.)

In my report of last year, I gave in some detail, the results of this investigation. Mr. Curtis and Mr. Eaton are continuing it but on a smaller basis. It was found necessary to do this on account of the lack of funds. Just now, three heifers are in the test but it is planned, if funds are available, to put the work on an extensive basis and to cover a period of five years or more. The three heifers which were continued in the work gave birth to normal calves during the summer, thus indicating that under certain conditions high rations of cotton-seed meal are not necessarily dangerous. These heifers were fed abnormally heavy rations of cotton-seed meal but with a view of getting unsatisfactory results, if possible. During the summer they were fed a half ration of cotton-seed meal based on 1 pound of cotton-seed meal to 100 pounds of live weight. During the winter this was increased to a full ration, averaging about 12 pounds per animal per day. Even with these large amounts two or three heifers have dropped normal calves.

Value of Velvet Bean Meal for Beef Cattle.

(Central Station Farm.)

Hundreds of inquiries are coming to our offices asking about the value of Velvet bean meal as a feed for beef cattle, dairy cattle, hogs, horses, and poultry. As this is a new feed, practically no work has been done to establish its true value. To place us in position to at least partially answer these question, Mr. Curtis last spring bought a carload of young cattle and divided them into two lots and is making a direct comparison of cotton-seed meal with velvet bean meal, when fed in conjunction with corn silage. This experiment does not close until November 1, or possibly later, so it is impossible to give the results just yet. The work has progressed far enough, however, to determine that velvet bean meal is very much inferior to cotton-seed meal for feeding beef cattle as 7 pounds of velvet bean meal are required to produce gains as rapidly as 5 pounds of cotton-seed meal.

Wintering Steers and Yearlings.

(T. L. Gwyn Farm, Haywood County.)

The beef cattle investigational work which has perhaps exercised the most influence in the State, has been the work done in coöperation with T. L. Gwyn, where a study has been made of various methods of getting steers through the winter months. I have, from time to time, reported the progress of this work. It is still being continued and the work last winter was as satisfactory as the two winters previous. Last winter five

lots of cattle were gotten through the winter in various ways. The first lot of steers was fed an average daily ration of 2 pounds of corn plus 10 pounds of hay; the second lot was fed an average daily ration of 15 pounds of corn silage plus 7 pounds of corn stover and straw; the third lot was fed an average daily ration of 15 pounds of corn silage plus 7 pounds of corn stover and straw; the fourth lot was fed nothing but winter pasture; the fifth lot was fed nothing but winter pasture. The winter period lasted 126 days, each steer in the first lot losing 35 pounds in weight, each steer in the second lot losing 52 pounds in weight, each steer in the third lot losing 76 pounds in weight, each steer in the fourth lot losing 18 pounds in weight, and each steer in the fifth lot losing nothing in weight. When corn is valued at $1.00 a bushel, hay at $15 a ton, corn silage at $4.00 a ton, corn stover and wheat straw at $10 a ton, and pasture at $1.00 per steer for 28 days, it cost $11.62 to feed each steer in the first lot all winter, $7.63 in the second lot, $7.91 in the third lot, $4.50 in the fourth lot, and $4.50 in the fifth lot. This pasture is nothing more than left over summer growth. That is, the stock is kept off of the ordinary pasture during the summer months. The grass is allowed to grow up and fall over and when the winter months come the animals are turned upon this summer growth and allowed to stay through the winter. This winter pasture is exciting favorable comments all through the mountain territory as many farmers realize now that these winter pastures afford the cheapest possible feed supply and at the same time give them an opportunity to enlarge the beef-growing capacity of their farms by providing extra feed in the winter time.

When summer pasture arrived these steers and yearlings were turned upon it and an account of their gains and weights and the cost of the gains and weights was kept until they were sold a few days ago. The steers in the first lot during the summer season of 140 days, gained 2.23 pounds; those in the second lot 2.5 pounds; those in the third lot 2.23 pounds; those in the fourth lot 2.38 pounds; and those in the fifth lot 2.48 pounds. The above gains were average daily gains. When pasture is charged at $1.00 per head for each 28 days, it cost $1.00 to make 100 pounds of increase in gain in the first lot; $1.42 in the second lot; $1.60 in the third lot; $1.49 in the fourth lot; and $1.43 in the fifth lot. When both the summer and winter feedings are taken into consideration, the cattle, therefore, which were on pasture all the time, both summer and winter, were raised very much more cheaply than those which were given other feed.

Winter Feeding of Breeding Cows.

(T. L. Gwyn, Haywood County.)

Mr. Gwyn is adding a breeding herd of Shorthorns to his cattle operations. This gives us an opportunity to add new phases to our investigational work. During the past winter the few breeding cows he has were divided into three lots and fed upon various rations. Each animal

in the first lot was fed daily 2 pounds of cracked corn, 2 pounds of cotton-seed cake, and 16 pounds of stover and straw; each cow in the second lot was fed 2 pounds of cracked corn, 3 pounds of cotton-seed cake, and 16 pounds of stover and straw; each cow in the third lot was fed 2 pounds of cracked corn, 3 pounds of cotton-seed cake, and 16 pounds of stover and straw. The animals used the past winter were too few to give conclusive results but when the expense of feeding them through the summer on pasture is added to the expense of getting through the winter, it is found that it cost from $24.66 to $27.51 to maintain each breeding animal a year. This is when corn is valued at $1.00 a bushel, cotton-seed cake at $35 a ton, stover and straw at $10 a ton, and pasture at $1.00 per head per month.

Wintering Breeding Cows and Fattening Steers in the Coastal Plain.

This work is being done upon the farm of Holderness and Shook at Tarboro. It is not possible, however, at the present time, to give anything except an outline of what is being done as the work has not gone far enough for a summary. A large herd of Aberdeen-Angus breeding cows and heifers and calves is involved in the work. The main object in working with the fifty breeding cows is to determine the effect of heavy and light feeding upon the cows and their offspring. The main object in working with the 21 breeding heifers is to determine the cost and best method of wintering in the coastal section. The main object with the 30 young calves is to determine the effect of heavy and light feeding upon the growth and maturity. By next year definite results will begin to come from this work.

Wintering Steers on Corn Silage.

(Iredell Branch Station Farm.)

During the winter of 1916-'17 32 high grade steers belonging to Mr. Eugene Transou of Stratford, were borrowed for use at the Iredell Branch Station Farm for the purpose of keeping accurate records of the cost of wintering beef steers. In addition to this a study was to be made of their grazing qualities during the succeeding summer. When the cattle arrived at the farm, January 13, 1917, they were divided into two lots. In the first lot the steers were each fed daily 15 pounds of corn silage, 10 pounds of corn stover, and 1 pound of cotton-seed meal; each steer in the second lot was fed daily 25 pounds of corn silage, and 1 pound of cotton-seed meal. Due to the fact that the supply of corn silage was exhausted too early it became necessary to incorporate other feeds in the ration during the last part of the experiment. From January 13, 1917, to April 24, 1917, when the experiment closed, it cost $10.14 to feed each steer in the first lot and $10.29 in the second lot. This is when cotton-seed meal is valued at $42.50 per ton, corn silage at $4

a ton, corn stover at $8 a ton, cotton-seed hulls at $20 a ton, and straw at $10 a ton. The steers in the first lot gained daily .42 of a pound while those in the second lot gained daily .39 of a pound. These results show very economical methods of wintering especially when the value of the manure is included in the statement. A total of 35.5 tons of manure was produced which, at present prices of fertilizers, is worth about $5.50 a ton.

This work, like the previous tests, shows that when cattle are being wintered they usually do better if some dry feed is incorporated with the corn silage. The cattle which were receiving silage alone were losing weight until corn stover was added, then they began to increase in weight rapidly.

The Value of Peanut Meal for Fattening Beef Cattle.

(Edgecombe Branch Station Farm.)

The excessive high prices of feeds have brought into prominence another new feed, namely, peanut meal. A large number of the cotton oil mills are manufacturing this meal and it has come to be one of our important commercial feeds. In our investigational work, we have established its economical place with poultry and swine but nothing, until recently, had been done in feeding it to beef cattle. In order to determine its feeding value for beef cattle, a test was inaugurated on the Edgecombe Branch Station Farm last winter. The experiment started January 10, 1917, and concluded on May 9 of the same year. Twenty-four cattle divided into two lots were employed. Those in the first lot were given peanut meal and corn silage; those in the second lot were given peanut meal, corn silage, and corn stover. When they were on full feed, the cattle in the first lot ate daily 9 pounds of peanut meal and 25 pounds of corn silage, while those in the second lot ate 9 pounds of peanut meal, 15 pounds of corn silage, and 10 pounds of corn stover. All of the cattle made satisfactory gains. Those in the first lot increased in weight daily 2.05 pounds, while those in the second lot gained daily 1.83 pounds. When the cattle were sold they were in good condition. The results of the test show that peanut meal is an excellent feed for fattening beef cattle. They cost 7 cents a pound in the mountains, and were sold, when fat, for 9½c a pound on the farm. When peanut meal is valued at $35 a ton, corn silage at $4 a ton, and corn stover at $8 a ton, some money was made on the animals. In fact, $71.26, therefore, was realized when the manure is not included. When the interest on the money borrowed and the labor were charged against the cattle, the manure is left as a clear profit.

SHEEP.

Sheep Investigational Work.

Sheep Investigational work is being conducted at the Central Branch Station Farm at Raleigh, the Iredell Branch Station Farm, and in Mitchell County. Not very extensive investigational work is under way at present. This weakness, however, will be remedied by another year as the work in Mitchell County will be developed rapidly.

In a general way the projects given the last year's report are being continued. These projects are:

1. *Sheep Breeding Work.*—The sheep breeding work is divided into two parts. In the first place Shropshire and Rambouillet rams have been mated with Barbado ewes to determine whether or not the Barbado blood renders our sheep in any degree immune to stomach worms and also to determine the effect of the introduction of Barbado blood on the season of breeding. It is claimed by some authorities that Barbado sheep do not succumb to the ravages of the stomach worm. Our work has not gone far enough yet to be conclusive on that point but we have no indication, so far, that this belief is true. It is also claimed by some that Barbado ewes breed at any season of the year. Our native ewes, of course, will not receive the attention of the ram except at stated seasons. This means that the lamb crop very often comes at unfavorable times. This phase of the work has not gone far enough to determine just what influence the trace of Barbado blood has upon the season of breeding although we do know that the pure bred Barbado ewes breed almost any month in the year.

The original Barbado ewes have been disposed of as their period of usefulness was passed but a number of half-bred and three-quarter-bred Shropshire-Barbado and Ramboillet-Barbado ewes have been saved for continuing the work.

In the second place these same breeding animals are being used in the experiment to determine the effect of different rations of cotton-seed meal upon the health and reproductive organs. It is claimed by many that heavy and continuous feeding of cotton-seed meal affects the breeding qualities of the breeding animals. At the present time no detrimental effects have been noticed although the work has not been going long enough to make our observations conclusive.

2. *Stomach Worm Experiments.*—The work conducted this year is a duplication of that given in my last report. This work is being pursued at the Central Station Farm and also at the Iredell Branch Station Farm, the object being to determine the effect of low, medium, and high conditions in the sheep in retarding the ravages of stomach worms. The lambs employed were divided into three lots. The first lot was gotten through the summer on pasture alone; the second lot on pasture plus one-half a pound of grain per lamb per day; the third lot upon pasture

plus one pound of grain per lamb per day. The results so far indicate that the infested pasture, with a medium ration of grain, is not sufficient to retard the detrimental effects of stomach worms in lambs. The lamb during his first summer is an exceedingly delicate animal and when placed upon pastures which are heavily infested with stomach worms, his chances of coming through the summer alive are very small unless he is fed a partial ration of grain to sustain his strength. At the Iredell Branch Station Farm, where one pound of grain was fed daily, only one lamb out of ten was lost. The small amount of grain no doubt saved the lives of the other nine. This problem is important only with lambs which are to be carried through the first summer for breeding purposes as lambs which are to be placed upon the market should be finished and sold before the season for stomach worms comes on.

3. *Winter Feeding of Ewes on the Iredell Branch Station Farm.*—During the winter of 1916-'17, 20 grade Shropshire and Rambouillet yearlings ewes were fed on the Iredell Branch Station Farm to determine the effect of different methods of wintering ewes. The ewes were divided into two lots, the ewes in the first lot being fed daily one-half a pound of grain and given the run of a good pasture during the day when the weather was fit; each ewe in the second lot was fed a similar amount of grain plus corn silage and kept up in a dry lot all the winter. The experiment continued from November 4, 1916, to March 26, 1917, a period of 142 days. When cracked corn is valued at $44 a ton, cottonseed meal at $40 a ton, wheat bran at $42 a ton, corn silage at $4 a ton and hay at $20 a ton, it cost $2.98 to get each ewe in the first lot (winter pasture lot), through the winter, and $3.75 to get each ewe in the second lot (dry lot), through the winter. At the same time the ewes which had the run of the winter pasture lost less in weight than did those which were confined in the dry lot and fed grain and corn silage. The ewes, of course, during the latter part of the winter had suckling lambs.

DAIRY CATTLE.

Dairy Experimental Work.

In the past three years, Mr. Eaton has conducted investigational work with dairy animals and dairy problems upon the Central Station Farm at Raleigh, the Pender Branch Station Farm, and in coöperation with some farmers in the Greensboro territory. The work being done by Mr. Eaton is used as a basis for teaching by the extension workers. As I have stated in previous reports, extension workers of the State who are leading the people along dairy lines, are very frequently embarrassed by the lack of accurate information. Southern institutions, so far, have done very little work along dairy lines, and for this reason it is harder for the dairy extension people, including those working in household economics as well, to be safe leaders than it is for extension workers in almost any other phase of live stock production. In a general way,

Mr. Eaton has been investigating feeding problems, growing problems, manufacturing problems, including those relating to the making of home cheeses. The scope of his work may be generally appreciated after reading the following results of his efforts:

Onion Contamination.

(Pender Branch Station Farm.)

One of the very greatest drawbacks to the dairy interests in the South, especially in Piedmont sections, is the presence of onion flavors in milk, cream and butter. In fact, onions grow so luxuriantly in some parts of the State that they are really the limiting factor so far as dairying is concerned. Mr. Eaton is continuing his study and trying to determine some practical and economical way of eliminating onion flavors. While he has not been satisfied with the results, still, he has made more progress than any one else in the country on this particular question. So far, he has used twelve Jersey and Holstein cows in his work and has studied over 6,000 samples of milk. It would be out of place for me, in this report, to review just how he has attacked the problems. As a result of his studies, he is warranted in making the following conclusions:

1. It is possible to remove the flavor on a commercial scale by blowing a current of heated air through the milk for a length of time dependent upon the degree of flavor.
2. Molasses feeds have a tendency to slightly weaken the flavor.
3. Onion flavor becomes more pronounced as the acidity of the milk increases.
4. A slight onion flavor has been found in two per cent of the milk samples twenty minutes after onions were eaten; the climax of the flavor is reached in from two to two and a half hours, and the flavor naturally disappears in four to four and a half hours, provided the cow does not eat more than three or four pounds of onion tops. Only two per cent of the samples have been found to show a slight flavor at five hours after onion tops were eaten.

As a safeguard against trouble from the fall crop of wild onions which will be on in a few weeks, the following suggestions may be found helpful:

Let dry cows and calves have the run of the onion pastures where possible.

Feed the cows heavily on molasses feeds or mix a liberal amount of feed molasses with your present grain mixture.

Remove the herd from onion pasture from to five hours before milking; this may slightly decrease your milk flow, but will improve the quality of your product if onions are present.

Winter Rations for Dairy Heifers.

(Pender Branch Station Farm.)

This is a continuation of the experiment inaugurated at the Pender Branch Station Farm in 1913, the object being to study the value of cotton-seed meal, as compared with wheat bran, when used in a ration for growing dairy heifers. This experiment the last winter continued from October 1 to April 1. The first lot of calves was fed a ration made up of bran and cotton-seed meal, half and half, plus corn stover; the second lot of heifers was fed a ration of cotton-seed meal alone plus corn stover. The calves in the first lot were allowed to fall off 25 pounds each during the winter months, while those in the second lot fell off 54 pounds each. The past winter, therefore, the replacement of half the ration of cotton-seed meal with wheat bran had a favorable effect upon the weights secured in the animals' feed. Corn stover is, of course, an exceedingly poor roughage for calves of this age but no other roughage was available. When wheat bran is valued at $35 a ton, cotton-seed meal at $40 a ton, and corn stover at $10 a ton, it cost $7.32 to feed each calf in the first lot (wheat bran and cotton-seed meal), through the winter months, and $7.55 to feed each calf in the second lot.

Spring and Summer Rations for Dairy Heifers.

(Pender Branch Station Farm.)

The heifers used in the winter work were carried into the spring and summer work to determine the value of the same grain rations when fed in conjunction with spring pastures. On April 1, 1917, the first lot of heifers, which was fed a ration of cotton-seed meal and bran half and half, was turned upon a rye pasture; the second lot of heifers, which had cotton-seed meal alone, was also turned upon the same pasture. They were upon this pasture for 61 days, each calf receiving daily during this time, one pound of grain and 1½ pounds of corn stover. During this time, the calves which had some wheat bran gained very much more rapidly than did those fed upon cotton-seed meal alone, as each calf, during the 61 days, in the bran-lot gained 96 pounds, while those in the cotton-seed-meal-lot gained only one-third of a pound.

Cracked Corn Versus Beet Pulp for Dairy Heifers.

(Central Station Farm.)

It is often claimed that beet pulp is a substitute, or at least a partial substitute, for pastures. It is also often claimed that calves fed upon beet pulp grow very much more satisfactorily than those fed upon a ration that does not contain beet pulp. If beet pulp will, in a measure, take the place of pasture it is an important thing for many Southern

farmers to know until pastures can be developed, but Mr. Eaton so far does not indicate that it has this virtue. A bunch of heifers was divided into two lots. The first lot was fed a ration made up of three parts cracked corn, one part cotton-seed meal, one part wheat bran, and hay and corn stover; the second lot was fed a ration made up of three parts beet pulp, one part cotton-seed meal, one part wheat bran and an equal amount of hay and corn stover. The experiment continued from May 1, 1916, to January 7, 1917. The calves eating the beet pulp did not make any more satisfactory gains than did those eating cracked corn. In fact, during this time they made practically the same daily gains as those in the first lot gained daily 1.16 pounds, while those in the second (beet pulp), gained 1.13 pounds. At the present time the cost of feeding the calves is just about the same.

Cost of Raising Calves.

(Pender Branch Station Farm.)

This is one of the old projects at the Pender Branch Station Farm. During the past year accurate records have been kept upon fifteen calves from birth to the age of six months. When grains are valued at $55 a ton, mixed hay at $20 a ton, silage at $4 a ton, stover at $10 a ton, whole milk at $2.50 per hundredweight, and skim milk at 50 cents per hundredweight, it has cost $8.18 to feed each calf until he is three months old, and $15.87 to feed each one until he is six months old.

Coöperative Calf Raising.

(Greensboro Neighborhood.)

This work, as given in my last report, was inaugurated two years ago with about fifteen farmers in the general neighborhood of Greensboro to determine the cost of raising dairy calves under practical farm conditions. This work was terminated August 31, 1917. Mr. Eaton has not as yet had time to summarize the results but will soon get them together and give them to the public.

Cooling Convenience for the Farm Home.

One of the most difficult home problems where cream is produced for the market is to keep the cream satisfactorily after it is produced. The authorities of several creameries of the State have requested us to study the problem of keeping cream in the home and try to develop some satisfactory inexpensive farm device for cooling it. Mr. Eaton did the first year's work in coöperation with 28 patrons of the Mooresville Cooperative Creamery in August and September of this year. He first studied the efficiency of a barrel cooler. Half of the above farmers were supplied with barrels and shotgun cans for holding the cream. These

barrels were connected between the wells and watering troughs and the arrangement was fixed so that when fresh water was drawn for the farm stock it would flow through and change the water in which the cream cans were kept. The cream from these two classes of patrons was churned separately and the butter scored by three judges. The experiment shows a remarkable reduction in the bacterial count in favor of the cooled cream, but the three judges did not make much difference in the score of the butter produced from the two classes of cream. On account of the fact that September was an unusually cool month the barrel cooler did not have a fair show. During this month there was only 47 per cent of sunshine and the average daily temperature was 3.1 degrees below normal. The experiment will, of course, be continued next summer.

Mr. Eaton also made a study of the efficiency of iceless refrigerators for a period of eight weeks during the summer of 1917. In the first year's work the results seem to indicate that iceless refrigerators have practically no value as there was only an average difference of 1.5 degrees between the average temperature of three of these refrigerators and the average mean atmospheric temperature. The average mean temperature during August and September, 1917, the time when the experiment was conducted, was 71.8 degrees, while the refrigerator temperatures were on the average only 1.5 degrees cooler.

HORSES AND MULES.

It is unfortunate that an appropriation has not been made to secure a competent man to look after the horse and mule work of the State. I hope that finances may soon become so a strong man can be secured and placed in charge of this work. So far, I with the assistance of Mr. Hostetler, have been doing what little work is being done with horses and mules. We really have only one project and this is being studied at the Iredell Branch Station Farm, Edgecombe Branch Station Farm, and Pender Branch Station Farm. All of the feeding work with horses and mules hinges around the question of the place of cotton-seed meal in the work animal's ration.

This piece of investigational work is not nearly completed; in fact, it is only really begun but still some valuable and definite facts have come to the surface. The results secured can be illustrated by calling attention briefly to the experiment upon the Edgecombe Branch Station Farm. Upon this farm six mules labor constantly at ordinary farm work. Three of these animals, since February 1, 1915, have had corn alone as the grain part of the ration. The kind of hay used has varied from time to time, but has consisted of corn stover, cowpea, crabgrass, Sudan and soybean hay. The other three mules—teammates of the first three—have, during all this time, had, in addition to the corn, small daily amounts of cotton-seed meal. The allowance, at first, was small as each mule now eats only one pound of cotton-seed meal daily. As a rule,

the corn was fed on the ear, the cotton-seed meal being sprinkled upon the ears. The following table gives a brief outline of the results obtained the first 29 months:

Lot.	*Ration.*	*Grain Eaten Yearly by Each Mule.*	*Annual Cost of Grain for Each Mule*	*Average No. Hrs. Worked Each Month by Each Mule.*	*Average Loss in Weight for 29 Mos.*
1	Corn	69.9 bu.			
	Roughage		$139.20	158	50 lbs.
2	Corn	61.6 bu.			
	Cotton-seed meal	296 lbs.	130.60	149	40 lbs.
	Similar roughage				

The table shows, when corn is valued at $2 a bushel, and cotton-seed meal at $50 a ton, that the small amount of cotton-seed meal cheapened the ration for each mule, $8.60 annually. When the amount of cotton-seed meal is increased and the amount of corn correspondingly decreased, and this is to be done soon—the annual saving will be still greater. During all this time the mules did almost equal amounts of work as measured in number of hours. Each mule in the corn-fed lot worked, on the average, 158 hours each month, while each one in the cotton-seed-meal lot worked 149 hours. All of the mules are in good health and have almost maintained constant weights. It is noticeable each spring, however, that the animals which have the small allowance of cotton-seed meal "shed off" earlier and more uniformly than do those eating corn as the sole concentrate.

Almost exactly similar results have been secured at the Iredell Branch Station Farm and at the Pender Branch Station Farm. When the results at Edgecombe are studied it is seen that one ton of cotton-seed meal saved 56 bushels of corn. In the Statesville work one ton of cotton-seed meal saved 11.2 bushels of corn plus 10.17 bushels of oats. At the Pender Branch Station Farm one ton of cotton-seed meal saved 34.4 bushels of corn.

POULTRY INVESTIGATIONAL WORK.

Dr. Kaupp,who has charge of the investigational work with poultry, is doing his work at the Central Station Farm, Pender Branch Station Farm, Edgecombe Branch Station Farm and Iredell Branch Station Farm. I cannot begin to give, in a report of this character, anything more than an outline of the work which Dr. Kaupp is doing. The only thing I will try to give is the results of some of his most characteristic pieces of investigation. In a general way, however, his efforts are directed along four general lines. In the first place he does a little extension work in the way of lectures, farmers' institute work, and displays at fairs. In the second place, he devotes much time to laboratory investigations which have to do directly or primarily with the questions

relating to diseases of poultry. In the third place, he devotes much of his time to carrying on the practical and scientific experiments upon the Central Station Farm at Raleigh. In the fourth place, he devotes some of his time to keeping in touch with the poultry work on the three Branch Station Farms mentioned above.

Raising Chickens on Peanut Meal.

(Edgecombe Branch Station Farm.)

Peanut meal has proven to be an exceedingly palatable and practical feed to use in conjunction with other feeds suitable for raising chickens. Last spring a flock of chickens came off the nest April 8 and were fed a ration made up of equal parts of peanut meal, ground oats, and cornmeal. These grains were mixed with buttermilk. At the end of eight weeks the chickens averaged 1.3 pounds each in weight. This was entirely satisfactory. The second flock was started on the same date and at the end of eight weeks each one of them weighed 1.2 pounds. A third flock came off April 13 and was handled in the same manner and fed in the same way. At the end of eight weeks the chickens in this flock averaged 1.4 pounds each in weight. In all a total of 27 test lots on this farm have been fed under farm conditions and the above three examples give a fair idea of the results. That is, peanut meal has a place as a feed for chickens.

Value of Milk in Raising Chickens.

(Iredell Branch Station Farm.)

At the Iredell Branch Station Farm something over 34 individual experiments have been run the last two or three years to determine the results when little chickens are raised without milk of any kind as compared with other chickens which are raised with skim milk. Two or three illustrations will indicate the results secured. For instance, one lot of chickens was hatched February 2. They were fed rolled oats, cornmeal, and wheat bran, the chickens receiving only water to drink. During the last four weeks of the test they were given a grain mixture in addition to the wet mash of wheat, oats, and cracked corn, equal parts. At the end of eight weeks these chicks averaged only .2 of a pound each in weight. They were attacked by diarrhea which caused a high death rate and interfered with development. On the other hand similar chicks run in parallel tests at the Pender and Edgecombe Branch Station Farms, except that the chickens on the last two farms were given milk to drink, were not attacked by diarrhea and weighed six times as much. A second lot of chickens at the Iredell Branch Station Farm came off the nest February 21 and were fed in exactly the same manner. At the age of eight weeks each chicken averaged only one-fourth of a pound in weight. On March 11 a third

lot of chickens was placed in the experiment and were given the same treatment and feed. At the end of eight weeks these chicks averaged .22 of a pound each in weight. During all this time check lots were run upon the other two test farms where milk was used and the chickens were from five to six times as large as those where buttermilk was not used.

Soybean Meal for Little Chicks.

(Edgecombe Branch Station Farm.)

As stated above it has been shown at the Edgecombe Branch Station Farm that peanut meal is an excellent feed for raising little chicks. Soybean meal is another new feed upon our markets and many inquiries are coming to Dr. Kaupp relative to its value as a chicken feed. To determine this point he has been doing some work at the Edgecombe Branch Station Farm in raising little chicks on a ration made up of soybean meal, wheat shorts, and corn meal, in equal parts, and mixed with sweet milk. One lot of chicks averaged 1.4 pounds in weight when eight weeks old. A second lot handled and fed exactly as the first, except that rolled oats was used in place of soybean meal, averaged 1.1 pounds in weight at the same age. On April 15 another bunch of chicks was placed on a soybean meal ration and at the end of eight weeks averaged 1.3 pounds in weight. A fourth lot, hatched April 22, was fed upon a similar ration and averaged 1.6 pounds at the age of eight weeks. Still another lot was fed in the same way and averaged 1.5 pounds when eight weeks old. In all sixteen lots of chickens have been fed as indicated above and the results have always been satisfactory so we have no hesitancy in recommending soybean meal as a good ration for feeding little chicks.

Feeding Laying Hens in Dry Lots as Compared With Range Conditions.

(Pender Branch Station Farm.)

This kind of work is being done at both the Pender and Iredell Branch Station Farms. In this study an accurate account is kept of everything that happens such as the amount of feeds fed, number of eggs laid, the strength of the chickens hatched, the diseases that appear, and the amount of sickness in the two lots. The results last year showed that the lot of Buff Rock hens, 32 in number, in the range lot laid 2,651 eggs. The same number of hens shut up a dry lot and fed the same ration as that fed in the range lot, laid only 314 eggs. These hens all had good treatment and good feed, the only difference being that one lot of hens had the run of the farm thus getting green feeds, bugs, and worms while the other one was enclosed in a dry lot and got none of these supplements.

This work is of particular interest to the town or city man who expects to keep birds shut up in close quarters.

The Control of Mites.

Dr. Kaupp has found that dry air-slaked lime, dry flowers of sulphur, and dry tobacco stems and leaves will not kill mites. These things are sold extensively. If the mites are killed the sulphur must be in solution and the nicotine in the tobacco must be free from the stems and leaves. When this nicotine is properly prepared it is effective. To properly prepare it 2½ pounds of stems and leaves should be put in sufficient water to cover it, boiled for one hour, the liquid drained off, and boiled down to one-fourth of a pint, this mixed with four ounces of water in which there has been put one tablespoonful of nicotine with one quart measure of plaster of Paris. This should be stirred, passed through a fly-screen sieve, when it is ready for use. Dr. Kaupp has worked out this formula and found it to be effective.

Laboratory Work.

Dr. Kaupp is a pathologist and he was brought here to devote much time to the study of diseases of all kinds of poultry. He has, consequently, devoted much time to laboratory studies particularly those phases which relate to diseases and pathological conditions. During the past year he has continued the study of the anatomy, histology, and physiology of the hen. As material presents itself he has also continued the study of tumors, roup, limberneck, and various kinds of poultry infections. In addition to this, he is doing some very original work in determining the digestive coefficient of feeds for fowls, a thing that has never been determined by investigators so far. His labortory has been very useful in the milk sickness problem that Messrs. Curtis, Wolf and Kaupp are studying, as Dr. Kaupp handles the pathological phases of that study.

Practically every one has noticed that fowls of all kinds are resistant to the usual pus-producing organisms. That is, it is a very seldom thing to find fowls of any kind carrying old sores of any sort. All other animals, including humans, are very susceptible to pus organisms which produce sores. Dr. Kaupp is spending much time trying to determine just why the fowl is resistant to this sort of trouble. If this can be determined it is very easy to see just how the application may be made in other animals and in humans, and prove to be a valuable piece of information.

Feeding Cottonseed Meal to Laying Hens.

(Central Station Farm.)

Last year I reported that a long-time experiment had been outlined with poultry to determine what effect cottonseed meal may have upon hens when fed for long periods of time. The first part of this work has been under way for two years. One pen of hens receives a ration made

up of 30 per cent of cottonseed meal; a second lot receives a ration made up of cottonseed meal 5 per cent; a third lot of hens receives a ration consisting of no cottonseed meal at all. Up to date, or at the end of the second year, 17 hens have died in the pen where the high portion of cottonseed meal has been fed, 17 in the pen where the low portion of cottonseed meal was fed, and 10 in the lot where no cottonseed meal was fed at all. These are high percentages as only 50 hens were used in each lot.

A second series of cottonseed meal experiments was started November 1, 1916. All of the birds used were hatched from our eggs during the spring of 1916. The first pen is receiving a ration made up of 1 per cent cottonseed meal; the second pen of hens is receiving a mash made up of cottonseed meal 5 per cent; the third pen is receiving a mash made up of 10 per cent. This series has not gone far enough to warrant any conclusions but up to date the death rate has been unusually high. In fact, not any of our work where cottonseed meal has been fed to poultry has been satisfactory, provided heavy amounts of cottonseed meal were used.

In a third series of experiments where cottonseed meal was fed to hens, the object was to make the other part of the ration so palatable and complete that the bad effects of cottonseed meal would not appear. powder 20 per cent, and ground corn 40 per cent; the second lot of hens received a ration made up of cottonseed meal 40 per cent, whole milk powder 20 per cent, and ground corn 40 per cent; the second lot of hens received a ration made up of cottonseed meal 30 per cent, meat meal 10 per cent, ground corn 30 per cent, wheat bran 10 per cent, ground oats 10 per cent, and skim milk 10 per cent; a third lot of hens received a ration made up of cottonseed meal 30 per cent, wheat bran 20 per cent, ground oats 20 per cent, and ground corn 30 per cent; the fourth lot of hens received a ration made up of cottonseed kernels 40 per cent, whole milk powder 20 per cent, and ground corn 40 per cent; the fifth lot of hens received a ration made up of gossypol (gossypol is the poison found in cottonseed meal), two-tenths of 1 per cent, wheat bran 30 per cent, ground oats 19.8 per cent, ground corn 20 per cent, meat meal 20 per cent, and whole milk powder 10 per cent. The experiment started December 1, 1916, and terminated May 21, 1917. The hens in lots 5 and 6 suffered with pendulous crops, becoming sick as a result of eating the cottonseed meal and all in lots 5 and all in lot 6 probably would have died if the feed had not been changed. At the end of the test all of the hens in the first lot were in good physical condition except one which was suffering with pendulous crop. All of the hens in the second and third lots came through in good condition. This preliminary study, therefore, gives us a basis for continuing more extensive work as some combinations of feeds with cottonseed meal promise some hope of overcoming the usual ill results when cottonseed meal is employed.

Breeding Work With Chickens.

(Central Station Farm.)

All the careful breeding work is being done at the Central Test Farm as this work requires almost hourly supervision by Dr. Kaupp or some of his assistants. Many breeds of chickens are being now used in this work. We now have Silver Campines, Silver Spangled Hamburgs, Dark Cornish, Silver Penciled Wyandottes, Golden Wyandottes, Columbian Wyandottes, Buff Plymouth Rocks, White Plymouth Rocks, Buff Orpingtons, White-Faced Black Spanish, Mottled Houdans, Black Cochin Bantams, Barred Plymouth Rocks, Single Comb White Leghorns, and Single Comb Rhode Island Reds. All of these breeds of chickens are used in some phase of breeding work. The biggest breeding problem we have is to develop a flock of White Leghorns which will produce more eggs than flocks already owned by farmers of the State, the object being, of course, to finally sell the eggs throughout the State. Complete records are kept of all these breeds as the number of eggs produced, number of infertile eggs, number of dead, chickens hatched, and the per cent of chickens raised. The main breeding problems are:

(a) A study of the fertility and ability to hatch of eggs resulting from single services by the males and by the alternation of the use of males.

(b) The result of the introduction of new males into breeding flocks.

(c) The result of mating daughters with fathers.

(d) The fertility and ability to hatch of white against brown shelled eggs.

(e) The breeding up of all of these flocks into better individuals and into greater egg producers.

Some of the above studies have gone far enough to draw some tentative conclusions. So far, the eggs with the white shells are more fertile than those with brown shells. During the year 1916 the white-shelled eggs were 8.7 per cent more fertile than the brown-shelled ones. And, in 1917 the white-shelled eggs had an advantage of 14.7 per cent. In the breeding work where the daughters have been mated to fathers, the result invariably showed a decrease in fertility from two to five per cent. When this sort of mating is allowed the number of chickens hatched from fertile eggs is also lower; in our work from 10 to 30 per cent. In that part of the breeding work where we have been noting the effect of introducing new males, we have seen that it is not always profitable especially if the new male has been inbred. In some of our work where the males have been allowed to be with the female only a few hours during the day the fertility was increased very materially, but in some other work the fertility of the resulting eggs was not perceptibly affected. The number of hens which each male is allowed to mate with has probably more to do with this than the number of hours he is with the hens each day.

It is necessary, of course, to continue the breeding studies over many years to get the desired results and reliable information.

The Effect of Mineral Matter Upon the Development of Young Chicks.

The most difficult period of the life of chickens is the first 48 weeks. The farmer or housewife who can manage to get chickens through this period feels that his greatest trouble is over as so many diseases attack the chicks at this young age and so many conditions cause them to develop unsatisfactorily. Many people are under the impression that one of the reasons why so many chicks are diseased and undeveloped is because they do not get a sufficient amount of the right kind of mineral matter in their foods. To study this question thoroughly and also to determine just what effect various mineral matters have upon the bodies of the young chicks, Dr. Kaupp has begun a careful piece of investigation. The first year's results are at hand except chemical analyses which are being determined at the present time.

All of the feeds used are analyzed as well as the bodies of the chickens after they are grown upon various rations. One lot of chickens is raised on a ration made up of rolled oats, wheat middlings, meat and bone meal, a second lot is raised on a ration made up of cracked wheat, cracked corn, and pinhead oats; a third lot is raised on a ration made up of wheat middlings, corn meal, meat and bone meal; the fourth lot is fed on a ration made up of whole wheat (not milling wheat), cracked corn and hulled oats. In addition to these rations some of them are fed an extra amount of chemically pure minerals, these being mixed with the feed. About all that can be said, so far, without having the chemical work before us is that the minerals have not had as much effect on the growth of the chickens as would be expected.

Shipping Fat Poultry to the Market.

As time goes on there will develop in this State, no doubt, very heavy fattening and shipping interests. In some states the question of fattening and shipping hens is a big one, and with hens, as with other stock, it is important to know how they should be fed just previous to being shipped to insure small shrinkage in weight. One lot of broilers was fattened for 21 days on a ration of buttermilk and mash and then shipped to New York City. The shrinkage in weight was 11.3 per cent; a second lot of hens was fattened on cornmeal, wheat middlings, ground oats, and buttermilk for 10 days and shipped to New York City. They shrank in weight 5.3 per cent. These birds, just before being started from Raleigh were each one given four ounces of whole corn and all the water they cared to drink. It seems, therefore, that the feeding of corn just before starting them on the trip reduced very materially the percent of shrinkage. In a third experiment to determine the percentage of shrinkage some fat hens which had been fed upon mash and

buttermilk were shipped to New York City. These hens were also, just before being started from Raleigh, fed upon some whole corn and the average shrinkage was only 2.6 per cent. Many other shipments have been made with about the same results.

The Use of Milk in the Ration for Little Chicks.

(Iredell Branch Station Farm.)

During the year of 1915-'16 the chick work conducted at the Iredell Branch Station Farm was for the purpoe of determining the influence of ordinary farm practices and farm feeding upon the development of chicks. The same feeds and methods of feeding were employed as have been in vogue on the farm during previous years but an accurate account was kept of all of the feeds eaten and the size of the chicks. During these two years the chicks were almost always attacked with diarrhea, the mortality was high, and the average weights at the end of the eighth week ran from .2 to .3 of a pound each. Last spring new rations were introduced and some lots were fed a limited amount of milk. The chicks which received a limited amount of buttermilk in addition to a good grain ration, averaged 1.3 pounds in weight at eight weeks of age, while those which were given water in place of the buttermilk with the same kind and amount of grain, averaged 1.1 pounds in weight at the same age. The buttermilk was, therefore very efficient.

In another set of experiments upon this test farm where buttermilk was used in conjunction with dry grains, chickens averaged 1.44 pounds in weight at the age of eight weeks. The water-lot of chickens averaged 1.32 pounds in weight. In a third test the buttermilk-fed chickens averaged at eight weeks of age 1.55 pounds, while those which were raised without buttermilk averaged 1.5 pounds in weight. In still another series of tests the chickens raised upon buttermilk averaged 1.5 pounds in weight at the age of eight weeks, while those which were raised upon water averaged 1.15 pounds in weight. In still another series of experiments the water-fed chicks at the age of eight weeks, averaged 1.13 pounds in weight against 1.43 pounds in weight, 1.36 pounds and 1.39 pounds in weight in the three lots where buttermilk was used to supplement the grains.

Many other similar experiments were made during the year at the Iredell Branch Station farm but the above results give just about the average of the results secured.

Raising Chicks on Soybean Meal and Buttermilk.

(Pender Branch Station farm.)

Dr. Kaupp has been doing considerable work at the Pender Branch Station Farm in determining the value of soybean meal in raising chicks when fed along with ground oats, corn meal in equal parts. The re-

sults below shows that he has proven soybean meal to be a valuable feed in this mixture.

In one test where this grain mixture was fed along with buttermilk the chickens at the age of eight weeks averaged 1.2 pounds in weight, while similar chicks in the second lot, receiving the same grain ration but water in place of buttermilk, averaged only .88 of a pound in weight.

In another series of experiments chickens which were raised upon the same grain mixture and buttermilk averaged 1.3 pounds in weight at the end of eight weeks, while those which were raised upon the same grain mixture but had water in place of buttermilk, averaged only .75 of a pound in weight. In still another series of experiments the chickens which were raised upon soybean meal mixture plus buttermilk averaged 1.13 pounds in weight at the end of eight weeks, while those which had the same grain mixture but water in place of the milk, averaged only .76 of a pound in weight.

Much more work of this character has been done at the Pender Branch Station Farm but the results given above are fair averages of the whole work which show that soybean meal is not only a valuable feed for raising small chickens but that buttermilk is remarkably efficient when compared with water.

Respectfully submitted,

Dan T. Gray,

Chief, Animal Industry Division.

REPORT OF DIVISION OF ENTOMOLOGY.

To the Director:

I herewith present report on the Entomological projects of Investigation under my charge, covering the period June 30, 1916 to June, 1917, inclusive.

1. *Pecan Insects.*—This project has been handled for several years by Mr. R. W. Leiby, Assistant Entomologist. Additional data on the life-history of many insect enemies of the pecan has been secured, covering points that must be considered in applying remedies for their control. As the study proceeds, its economic importance becomes more apparent. Thus in the early summer of 1917, many pecan trees were seriously injured or endangered by the attacks of the Pecan Leaf Case-bearer. A few years ago we would not have known how to deal with such an outbreak, but as the studies of Mr. Leiby had already revealed the essential points in its life-history, he was prepared to specify the manner and time to apply remedies for it, and his tests gave satisfactory control.

This is a good illustration of what I conceive to be the true function of investigations of this character. Here was a crop which at the time these studies began was of minor importance with only a few known serious insect enemies in this State. Studies were made upon this case-bearer when it was not known to our growers as a serious pest, and as a consequence of these studies remedies could be applied as soon as it did assume importance.

2. *Corn Stalk-borer.*—This project also has been conducted by Mr. Leiby during the past year, with very little participation on my own part. The observations have been made chiefly at the Coastal Plain Station (Edgecombe County). Additional and more definite data has been secured, which as the study covers a longer period will permit a more accurate averaging of results.

3. *Potato Spraying.*—The disastrous floods of 1916 rendered the results of the work of that year at the Mountain Station (Buncombe County) of little value. During the time covered by this report, the work of 1917 has been under way. It may be added that as this is being written (after the period covered by this report) the data from the work of 1917 has been secured, and is highly satisfactory. Already the work has gone far enough to furnish a safe basis for some extension propaganda for the spraying of potatoes, and extension circular No. 48 on "Spraying Irish Potatoes" was issued and widely distributed in the spring of 1917.

4. *Peach Spraying.*—The work done on this project by Mr. S. C. Clapp and myself at the Piedmont Station (Iredell County), was suspended after the season of 1915 for a variety of reasons—late frost and early drought curtailed the crop of 1916, while the resignation of Mr. Clapp to take charge of the Mountain Station, and the increased

office duties assumed by myself upon the entry of this country into the war, prevented its continuance in 1917. Furthermore, most of the points which we had in mind were well answered by the years of 1914-15. (1) We found that the commercial lime-sulphur at 1 gallon to 49 gallons of water with arsenate of lead added, when persistently used as a summer spray would result in final injury to the trees, although this was not evident the first year and did give better color to the fruit than the standard self-boiled lime-sulphur with arsenate. (2) The counts of premature "drops" indicated a greater percentage of curculio injury near woodlands. (3) The use of soap as a "spreader," or of flour-paste as a "sticker," did not appear to render the arsenate more effective against the Curculio. (4) The use of 1 lb. of blue-stone (copper-sulphate) in 50 gallons of spray (commercial lime-sulphur) did not lessen the amount of rot but did produce a smutty appearance of the fruit and seemed to delay maturity. (5) Of the several combinations tested none gave better average of results than the standard self-boiled lime-sulphur with arsenate. (6) The sprayed trees matured a more highly colored fruit with less loss from rot than did the unsprayed ("check") trees.

5. *Soap and Water for Aphids.*—No new data.

6. *Insect Life of North Carolina* (*Insect Survey.*)—To work out the areas of distribution of our native insects, to determine the "life-zones" of the State, and perhaps ultimately to be able to classify our insects into groups according as they occur throughout, or only in restricted parts of our state—these points have been sought in this project which we well know may occupy the attention of more than one generation of entomologists. It is a long-time project, embracing the collecting and recording of scores of thousands of specimens, of thousands of different species of insects. It has been my own favorite project for many years, and in its prosecution I have enlisted the efforts of every assistant so far as circumstances would allow. Yet it is conducted piece-meal, and does not occupy the exclusive or principal attention of any one of the workers. Many facts, odd, instructive or mildy startling, have been placed on record in regard to insects, some of which are destructive, some only potentially destructive, and some apparently "neutral" in their relations to man. Examples: The Yellow-fever mosquito (*Stegomyia fasciata*) is common at Raleigh in late summer. The Northern Grape Root-worm (*Fidia viticida*) (a serious pest in the region of the Great Lakes) has been taken at Raleigh in several different years. The Sweet Potato Weevil (*Cylas formicarius*) (regarded as a coast-wise species) has been recorded from Southern Pines and from Hendersonville in the mountains. A species of scorpion-fly (*Panorpa rufa*) which for years was known only from a single specimen in "a British Museum," has been taken in at least two localities—and another scorpion-fly (*Panorpodes caroliniensis*), has been taken only in the mountains of North Carolina, while its nearest known relative is a native of Japan! Many more

instances of this sort might be mentioned. This project is designed to gradually throw a comprehensive light upon our whole insect fauna, and will of necessity require long continuance. I wish it were possible to employ a skilled collector to assign solely to this project.

7. *Field Studies of Black Corn Weevil.*—In the fall of 1916 Mr. Leiby and myself began some field studies of the black Corn Weevil (*Calandra oryzae*) at the Black Lands Station (Washington County) to determine what methods of culture or of handling of the corn crop would affect its abundance. As yet it is too early to discuss the details of this.

Acknowledgments.

It is a pleasure to report that the entire work has gone forward with only the best of feeling among the several workers concerned, and to acknowledge the kindly support of yourself as director. All who have ever been associated with this office are still its friends, and although the war-period upon which we have now entered may bring modifications of plans or changes in personnel, yet I believe that the work which is being prosecuted is giving substantial returns, which cannot but strengthen our people for the tasks ahead.

Very respectfully submitted,

FRANKLIN SHERMAN,

Chief in Entomology.

REPORT OF ENTOMOLOGIST.

To the Director:

I submit, herewith, a brief report of the work in Entomology for the fiscal year ending June 30th, 1917.

During the past year we have completed the study of the biologic phases of the study of the Southern Corn Bill Bug (*Sphenophorus Callosus Olivier*) and the detailed results have been published in Technical Bulletin No. 13. At the same time the more economic phases of this subject were published in Extension Circular No. 19. This then closes the Adams Fund Project on the Genus Sphenophorus save for the writing up of the morphological phases of this genus for technical magazines.

The Adams Fund Project on the Genus Chrysomphalus has been pursued during the past year, and, at the present time, we are engaged in writing up the biological phases of this genus as it relates to the Gloomy Scale.

The Bruchus Project has progressed satisfactorily, especially in regard to a study of a new method of treating cowpeas to prevent weevil injury. A detailed report of these results has been published in the *Journal of Economic Entomology,* February, 1917, under the title "Lime as an Insecticide." The results of these experiments place in the hands of the farmer for the first time a safe and effective remedy for these pests, and, at the same time, one which is so simple and cheap any farmer can make the application. Since reporting on these experiments, further experiments on a larger scale have shown that where cowpeas are stored in large amounts, the lime may simply be spread in a layer on top of the peas and still accomplish the same result.

The Hatch Project on the correlation time of planting and the injury to corn by certain corn insects, especially the corn root worm, has been continued. Unfortunately, the spring was so backward and wet that our results are not satisfactory. In some cases plantings have been interfered with, but, as a rule, we have made fairly regular plantings at the Central Station, the Pender Branch Station, Washington Branch Station, and the Edgecombe Branch Station. However, we do not expect to be able to draw any very reliable conclusions from the results of these plantings this year. This in a brief way covers the work during the past year, which has been marked by satisfactory progress along all lines.

Respectfully submitted,

Z. P. Metcalf,
Entomologist.

REPORT OF THE DIVISION OF HORTICULTURE.

To the Director:

The experimental work of the Division of Horticulture is being continued along the lines of the projects laid down in previous reports. Some work that has been in progress for a number of years has been completed as far as the field work goes and the data are being prepared for publication. Some new projects have been taken up.

PECAN WORK.

(Coastal Branch Station, Truck Branch Station and Piedmont Branch Station.)

1. *Variety Testing.*—Twenty-two of the most important southern varieties are included in this test which has been carried on for 10 years. Gratifying results are being secured from this work as certain varieties are showing marked adaptability to North Carolina conditions while others are proving to be undesirable. At this time valuable recommendations regarding pecan varieties for planting in this State can be made. It has been shown that certain varieties that are very satisfactory in the Gulf Coast Section are owing to our shorter growing season almost worthless here. It is evident from even the comparatively short length of time that the experiment has been conducted that the variety factor is of extreme importance in determining the success or failure of a pecan orchard in this State.

II. *To determine the value of the Pecan as a commercial proposition in this State.*—At 8 years of age the experimental pecan orchards bore what might be considered their first commercial crop. At the age of 10 years, these orchards show that by the proper selection of varieties and careful attention to cultural practices pecans are valuable in the Coastal Plain of North Carolina as a commercial crop. As a result of the test at the Piedmont Branch Station, it is strongly indicated that as a commercial proposition pecan growing should be confined entirely to the Coastal Plain.

III. *Securing individual tree performance records*—Performance records of the individual pecan trees in the experimental orchards at the several stations were continued this year as in former years. As a result of this work, it is noted, that trees of the same variety under identical conditions are uniformly heavy yielders while others are very poor yielders; that some produce uniformly large nuts and others uniformly small nuts. These results indicate the possibility of bud variation in the pecan and suggest the value of bud selection in propagating and top-working pecan trees.

IV. *Cultural practices.*—The value of correct cultural practices such as tillage, the use of cover crops and leguminous crops, is clearly shown

in the increased size of trees and in the increased size and number of nuts produced when compared to trees and their products grown in sod.

V. *The value of the different varieties as regards cracking quality.*—The cracking test is a necessary adjunct to the performance record of a given variety in determining its value in a certain section. Very often a variety is highly satisfactory from a productive standpoint but the cracking test shows the variety to be nearly worthless from an utility viewpoint. The cracking test determines the per cent of unbroken halves the variety will crack out, the per cent of shrunken kernels, the per cent of physiological spot, the per cent of faulty nuts, the shape and size of the kernel, the texture, quality and flavor of meat, the per cent of meat, and the thickness of shell. Such a cracking test was conducted this year, as in former years, and as a result certain varieties that were satisfactory from a productive standpoint proved to be totally unsuited to North Carolina conditions.

VI. *Top-working undesirable varieties.*—Progress should be reported in the experiments in top-working pecans. The investigations show that good results can be secured by both the "patch bud" method and the "slip bark graft" method. While this has not been concluded, results indicate that success rests as much in the selection of suitable bud and graft wood as in the technique of the operator. By using properly selected buds, an average "live" of 85% has been secured by the "patch bud" method and a "live" of 70% by the "slip bark graft" method.

VII. *Bud selection.*—As the individual performance records of the different trees suggest the possibility of improving and standardizing individual yields by bud selection, several trees of known performance ability were top-worked with buds from a high yielding tree while several trees were budded from a low yielding tree. It will be several years before results can be secured from this work.

VIII. *Pecan breeding.*—The test orchard in pecan breeding work was set in the spring of 1914. Most of the trees have made a satisfactory growth but no nuts have yet been produced on any of the trees.

PEACH WORK.

1. *Peach breeding work* (Truck Branch Station).—It is the object of this project to produce (a) earlier maturing white and yellow fleshed varieties of peaches, (b) earlier freestone varieties of both white and yellow fleshed peaches, (c) varieties hardier in bud, (d) varieties with a longer resting period.

Selection, production of seedlings, and crossing are the methods of procedure in this project. To furnish working material to carry on this project, a variety orchard containing over 60 different varieties of peaches was planted at the Truck Branch Station in Pender County this last season. Very little can be done on this project until this orchard reaches bearing age.

II. *Hardiness of flower buds of different varieties.*—Using the variety

orchards of the different branch stations and also commercial orchards data have been collected on the susceptibility to cold injury of different varieties.

III. *Variety Tests.*—The testing of different varieties on the several branch stations has been contiuned from year to year.

IV. *Rest Period Studies*—The influence of different degrees of pruning in prolonging the rest period was studied. It is evident that severe pruning causes a prolongation of the rest period in winter which is a highly desirable condition for peach trees in this State. Often the prolongation of the "rest period" in winter a few weeks means the difference between a crop and a crop failure.

V. *Summer Pruning Young Peach Trees.*—Among fruit growers in this State it is a debatable question whether or not it is advisable to summer prune young peach trees. To gain some information on this question a number of trees in an orchard that had just been planted were summer pruned while the remaining trees were not. It will be next year before results can be secured from this work.

VII. *Thinning Peaches.*—During the last three seasons experiments in thinning peaches have been conducted at the Coastal Station and the Piedmont Station. Results from these experiments show conclusively the value of thinning in producing fruit of larger size, more uniform size, and of higher color. It is evident, too, that proper thinning increases the vigor and longevity of the tree.

THERMAL ZONE WORK.

The work begun in 1912 in coöperation with the Weather Bureau of the United States Department of Agriculture to study the phenomena known as Thermal Belts was completed in 1916 as far as the field work went. Since that time, the vast amount of records collected at the different stations are being worked over by the experts of the Weather Bureau under the direction of Professor Cox in charge of the Chicago Station. A topographical map of Western North Carolina has been prepared with contour lines showing the locations of the observation stations and the mountainous nature of the surrounding country. In order to make this work of practical as well as of scientific value, we will prepare this winter a map showing the location of railroads to available fruit zones at 500 foot contours from 1,500 to 3,500 feet.

VARIETY WORK IN POMOLOGY.

Observations, on the behavior of the better known varieties of fruits in the different sections of the State, have been made on the Experimental substations and on commercial orchards throughout the State. Much time and care has been taken in writing and revising descriptions of almost all of the important varieties of fruits grown in this State. These descriptions are to be used in publications and are being used in the office as an aid in identifying varieties of fruit sent in from over the State.

NATIVE FRUITS OF NORTH CAROLINA.

Considerable time has been spent on this subject and it is being pushed towards a conclusion. The place of origin, the history and the description of a number of varieties of North Carolina origin have been added to the already large list. Where opportunity offered, the descriptions, of varieties secured previous to this season, were verified or corrected. Paintings and photographs have been made of the most important varieties.

DRYING, EVAPORATION AND DEHYDRATION OF FRUITS AND VEGETABLES.

As a food conservation project, investigations were made regarding the different methods of preserving fruits and vegetables by drying. To supply the demand for information regarding drying a bulletin entitled "How to Dry Fruits and Vegetables for Home Consumption" was prepared. That there was a large amount of interest in drying has been shown in the requests for this publication. As the result of our investigations along this line, a dehydrating plant of commercial size was located at the State Hospital. It has been giving very satisfactory results.

VEGETABLE WORK.

The vegetable testing work as outlined in former reports has been continued and data recorded. Confirmatory data were secured at the Pender Substation on the production of varieties of sweet potatoes most suitable for storage purposes. Work was begun on the Mountain Substation on the production of late cabbage for storage purposes. Various methods of storing this crop are now being tried to hold over the cabbage for late winter and early spring markets.

Since the land has been cleared and drained on the black soil belt station at Wenona, a number of tests were begun this season to try out in a preliminary way the kinds of vegetables best suited for growing in muck soils. A full line of vegetables were planted in the spring and careful notes kept on their behavior during the summer. Confirmatory data were secured on the behavior of many of these classes of vegetables by the planting of a full garden and noting the planting dates best suited to each crop. Sufficient data were secured to warrant the more extensive testing during the coming season of the types of vegetables found to be best suited to that type of soils.

W. N. Hutt,
Chief, Division of Horticulture.

REPORT OF THE HORTICULTURIST.

To the Director:

I submit the following report for the year ending June 30, 1917:

The investigations being made at West Raleigh are along the line of original research in connection with the Rotundifolia grapes, and are supported by funds appropriated for the purpose under the provision of the Adams act. They have been in progress since 1907, reports in bulletin form having been made from time to time since the publication of the first one in April, 1909. These have constituted a distinct addition to the literature on the subject of heredity and have been widely quoted in contemporaneous writings.

The department now has growing in the experimental vineyard something over 4,500 seedlings, which have been secured by hand-crossing and which represent all of the series from No. 3 (1910), to No. 9 (1916), inclusive. Series 1 and 2 (1907 and 1908), have been discarded. Of the earlier series, large numbers have been eliminated owing to determinations having been made as to their lack of value. The most promising individual plants have been transplanted to more permanent positions for further study and use in the making of future crosses.

During last year, a large number of crosses were made in accordance with plans previously outlined, but owing to vicissitudes in connection with the season, relatively few seedlings were obtained this year. During the year, however, a large number of seedlings which had not fruited up to the present year, yielded a large amount of data which has been secured and recorded.

During the year, also, partial report was made as to the progress of the investigation in connection with the inheritance of sex. This report appears in Technical Bulletin No. 12, published in January, 1917. The principal points determined and reported therein being the establishment of the facts that—

1. Hope, the first discovered hermaphrodite vine of the species Vitus rotundifolia, is self-fertile;
2. That the floral types in Vitus rotundifolia are transmitted to the progeny of crosses in definite ratios;
3. That upright stamens in hermaphrodite flowers of Vitus rotundifolia are correlated with normal, viable pollen, and self-fertility; and, conversely, that the reflex type of stamen in hermaphrodite flowers is always associated with defective pollen, and self-sterility; and,
4. That it seems very probable that self-sterility in Rotundifolia grapes has come about through the suppression of the pistils and the consequent power to function. Removal from the wild condition and cultivation exerts considerable effect in the line of regeneration of the pistils.

Not all of the ratios by which floral types are transmitted have been determined and further report on this matter will be made at some future time. The work, as outlined in a general outline, includes various studies along the following lines:

1. Inheritance of sex.
2. Productivity.
3. Inheritance of colors of fruits.
4. Inheritance of size of fruits.
5. Quality characters.
6. Hybridization with other species.

During the past year, data on various points bearing upon these several lines of study have been secured and recorded, but as it was incomplete, no further report was made than that mentioned above. During the spring further crosses were made and seeds from these will be available in the autumn.

In connection with the work on hybridization with other species, investigation is being made with respect to resistant stocks. Numerous individuals have been propagated upon native stocks for this purpose.

In closing this report, the writer wishes to commend Mr. L. R. Detjen, who has been associated with this work from its inception, for his zeal and fidelity.

Respectfully submitted,

J. P. Pillsbury,

Horticulturist.

REPORT OF THE VETERINARY DIVISION.

To the Director:

I herewith submit a report of the work of the Veterinary Division for the year ending June 30, 1917.

The following work has been performed during the year:

"Contagious Abortion" Infection.—Effort has been continued to determine the prevalence of and suitable control measures for "contagious abortion" infection (abortion disease), among various classes of animals, but with particular reference to dairy cattle.

Attempt has been made to recognize its presence in the various herds by the history obtained from those herds as to abortions, premature births, inflammations of the uterus following calving, with or without retained afterbirth (fœtal membranes), sterility of females (temporary and permanent), frequent inflammation of the udder, calf scours (white scours) and calf pneumonia.

Likewise, several kinds of laboratory examinations and tests of material obtained from the animals were made to discover the presence of the specific infection. The examinations consisted of microscopical and cultural, the tests of complement fixation and agglutination.

Some cases of sterility have apparently been rendered fertile again by massaging affected ovaries and by flushing the uterus, having its mucous membrane altered.

Influenza (Shipping Fever) Complications.—Some study has been made as to the nature and control measures of the serious complications following influenza of horses and mules.

The rather frequent finding of a bipolar staining organism in such cases led to the belief that it belonged to the Hemorrhagic Septicemia group. The clinical symptoms and lesions likewise often suggested the presence of such an organism.

Opportunity was afforded to prepare some bacterial vaccine containing this organism and to observe apparently good results in a number of affected British horses and mules at the British Depot, at the Spencer stock yards. It is believed the best results would be obtained by using this product as a preventive agent, or the earlier use as a curative, the better.

Laboratory Examinations.—As in previous years, numerous laboratory examinations have been made of materials sent us for diagnosis and identification. Among such materials were various tissues, blood, milk, feed, pus, foreign matter removed from animals, parasites, and other material.

Several infectious diseases were diagnosed by injecting suspected material into laboratory animals and reproducing the disease.

Autogenous bacteria were made for the treatment of a number of infectious diseases of animals.

Autopsies were conducted upon some twenty laboratory animals for other departments of the Station.

Visits to and Autopsies Upon Station and College Animals.—Some forty visits were made to sick and wounded animals belonging to the Station and the College of Agriculture. Autopsies were held upon some twenty experimental and college animals. Slaughter examinations were made of some twenty experimental animals to be used for market puposes.

The tuberculin test was applied to the college dairy herd consisting of forty-two animals. No reaction, or even suspicious reactions, were obtained from either the subcutaneous or intra-dermal tests.

Changes in Personnel.—Dr. J. I. Handley, who had been largely conducting the laboratory examinations, and doing some of the field work, resigned January 1st. Since that time, the laboratory work has been carried on by Messrs. J. A. Simms and N. B. Tyler.

Recommendations.—In view of the fact that the direct and indirect losses from the various diseases of animals in the State are quite large, and that the knowledge concerning the causes and the control of many of these diseases is quite limited, we respectfully recommend that adequate provision be made for investigational work in animal diseases.

The following from the last official government reports gives an estimate of the direct losses from deaths of animals in North Carolina for the past year ending March 31, 1917. The indirect losses from sickness and unthrift, but not resulting in death, amount to fully as much as the former. Losses in pet animals and fowls not determined.

April 1, 1916, to March 31, 1917.

Horses having died, 3,700; Av. price, $125	$462,500	
Mules having died, 4,000; Av. price, $150	600,000	
		$1,062,500
Milk cows having died, 9,765; Av. price, $39	$380,000	
Other cattle having died, 11,284; Av. price, $19	208,909	
		788,909
Sheep having died, 3,920; Av. price, $4	$15,680	
Lambs having died, 1,000; Av. price, $3	3,000	
		18,680
Swine (all diseases, 5 per cent of total), 77,500; Av. price, $9.70		751,750
		$2,621,839

Respectfully submitted,

G. A. Roberts,
Veterinarian.

REPORT OF THE DIVISION OF PLANT PATHOLOGY AND BACTERIOLOGY.

To the Director:

The following brief report covers the work of this Division for the fiscal year ending June 30, 1917:

Soil Bacteriology (in Coöperation with the Division of Chemistry). Since the investigations upon this problem were primarily chemical in nature, the work has been taken over in its entirety by the Division of Chemistry.

Apple Root Rots.—A report, covering the result of investigations to date, on this project has been prepared and has appeared in the *Journal of Agricultural Research.* Subsequently, our findings have been confirmed at the Virginia Station and the disease has been reported from New York and Indiana.

Lettuce Drop.—The studies which were previously reported as in progrèss will be completed during the coming year and submitted for publication as a Station bulletin.

Watermelon Wilt Control.—Further attempts to improve the rind of the North Carolina wilt resistant melon, called "Conqueror," are being made by the Office of Cotton and Truck Investigations of the United States Department of Agriculture. Our work on this project has been confined to a multiplication of the seed for distribution within the State.

Control of Tobacco Wilt (in Coöperation with the U. S. Department of Agriculture).—It has been found that tobacco wilt can be successfully controlled by crop rotation. The results of the studies of natural resistance of species and varieties of tobacco, both native and foreign, of the influence of chemicals and fertilizers, and of various systems of cropping and rotation are given in Bulletin 562 of the U. S. Department of Agriculture in coöperation with the North Carolina Agricultural Experiment Station. A report covering the distribution of tobacco wilt within the State and the occurrence of the same organism upon a considerable number of additional hosts, both weeds and cultivated plants, has appeared in *Phytopathology.*

Aside from these projects, studies have been made of a disease of summer squashes and a technical report upon these studies has appeared. A blight or wilt disease of soybeans, caused by an organism identical with the one which causes cowpea wilt, has been investigated and duly reported. Furthermore, it has been found from studies conducted in coöperation with the Division of Animal Industry, that white snakeroot, Eupatorium urticæfolium, is the cause of trembles. A report containing the data upon which this conclusion is made, has appeared and it is planned during the coming year to issue a complete report of these studies.

Considerable time has been devoted to the Plant Disease Survey and to the letters of inquiry relative to the more common plant diseases.

Changes in the staff have involved the resignation of E. E. Stanford, who has been appointed to work with the Bureau of Chemistry at Washington, D. C.

A number of publications, together with brief scientific notes, reviews of books and scientific articles, have been prepared by this Division during the year, the most important of which are listed as follows:

1. A squash disease caused by Choanephora cucubitarum. Jour. Agr. Research, v. 8, No. 9, 319-328, Pls. 3, 1917. (By F. A. Wolf.)

2. Fusarium blight or wilt of the soybean. Jour. Agr. Research, v. 8, No. 11, 421-440, fig. 1, Pl. 1, 1917. (By R. O. Cromwell.)

3. Control of Tobacco Wilt in the flue-cured district. U. S. Dept. Agri. Bul. 562, 1-20, figs. 5, 1917. (By W. W. Garner, F. A. Wolf and E. G. Moss.)

4. Studies on Bacterium solanacearum. Phytopath., v. 7, No. 3, 155-165, fig. 1, 1917. (By F. A. Wolf and E. E. Stanford.)

5. Eupatorium ageratoides, the cause of trembles. Jour. Agr. Research, v. 9, No. 11, 397-404, Pls. 3, 1917. (By R. S. Curtis and F. A. Wolf.)

6. Xylaria root rot of Apple. Jour. Agr. Research, v. 9, No. 8, 269-276, fig. 3, Pls. 3, 1917. (By F. A. Wolf and R. O. Cromwell.)

7. Studies on resistance of tomatoes to bacterial wilt. N. C. Expt. Sta. Ann. Rept. 40. (By E. E. Stanford.)

Respectfully submitted,

FREDERICK A. WOLF.

REPORT OF DIVISION OF MARKETS AND RURAL ORGANIZATIONS.

To the Director:

This report is for the year ending June 30, 1917, and covers the experimental work in the Division of Markets and Rural Organization, conducted jointly by the North Carolina Department of Agriculture and the North Carolina State College of Agriculture and Engineering, in coöperation with the United States Department of Agriculture under the agreements and plans entered into by these institutions for the conduct of all agricultural work of this kind in the State.

INVESTIGATION OF PRODUCER'S PRICES.

The prices received by producers for strawberries, Irish potatoes, cotton, corn, peanuts and soybeans, have been investigated to determine the marketing conditions under the varying circumstances prevailing in different communities. These investigations show that the small size farmer whether he be a grower of strawberries or a producer of cotton, does not receive as much for his products as the farmers with larger crops. The large sized producer need not depend upon local markets. Dependence upon a local market makes a monopoly of that market and means generally lower prices, especially for the small size producer. The large size producer may be paid a higher discriminatory price on a local market to prevent his seeking an outside market, or to prevent farmers organizing, or to break up a farmers' organization when formed. The local market, generally, does not encourage grading farm products. To avoid any hard feeling from seeming to discriminate, local buyers are inclined to pay a flat price for produce. Such a practice is recognized by the trade as being responsible for farmers not grading their products as they should. If farmers do not know the grade of their products, or if they do not grade and pack them according to market requirements, they are in no position to sell advantageously in outside markets. This method on the part of buyers of not paying for food products strictly according to quality and grade is a discriminatory practice, which is prohibited by section 5 of the Food Control Act, according to which all discriminatory practices of licensed middlemen are unlawful.

Early Irish potatoes sold this year at prices never heard of before, notwithstanding the unusually large crop, shipments amounting to 4230 cars as compared with 2760 cars in 1916. Many North Carolina growers averaged \$8 per barrel for their crop. The Carolina Potato Exchange averaged \$7.94 per barrel for all grades of potatoes shipped between June 1st and July 2d, or \$8.03 per barrel for grade one, \$5.43 for field run, and \$3.34 per barrel for culls. The average price obtained by growers in different parts of the State, according to special reports,

was $6.83 per barrel for grade one and $4.68 for grade two. The average price received for contract potatoes of all grades as reported was $4.68 per barrel, as compared with $6.79 per barrel for potatoes which were not contracted for. Potato growers in North Carolina lost nearly a million dollars through contracting ahead last spring. If growers would save enough this year to buy seed and fertilizer for cash, then they would be free to organize to sell on grade at the market price.

The New York market between May 30th and June 28th averaged, according to the market news service reports, $9.05 per barrel for grade one in 1917 and $4.11 in 1916, and $6.28 per barrel for grade two in 1917, and $2.62 per barrel in 1916.

This Division, in coöperation with the Virginia Division of Markets, is inaugurating a new policy this year in regard to the marketing of the peanut crop. Information is being gathered from all the peanut-producing states concerning quality and yield of crop in order that the growers, in a conference to be held at Suffolk, Virginia, on November 20th, may have the necessary knowledge to determine what, under existing conditions, would be a fair price for this year's crop. Notwithstanding the increasing high cost of production, the price of peanuts remained practically the same during the years 1910 to 1916, inclusive. The average price of peanuts in North Carolina during the months that the farmer disposes of his crop, according to the Bureau of Crop Estimates, was 4.5 cents per pound in 1916, and 4.6 cents per pound for the period from 1916 to 1917, inclusive. The price rose to 7.26 cents a pound on an average during the months from May 15th to September 15th, inclusive, 1917. This would indicate that the farmers of this State received 2.76 cents a pound less than they would for last year's crop, or in the neighborhood of $4,226,731.99 less than they would had they been paid according to prices quoted in later months. The above figures are based upon the Bureau of Crop Estimates reports. But if the calculations are based upon special reports of producers' prices, the peanut growers would have received $4,904,232.22 more had they been able to sell their crop at the prices prevailing between May 15th and September 15th, 1917. This is on the assumption that the 1916 peanut crop is the same size as that of the census year 1909. Beside prices, the Suffolk conference will consider cost of production, feasibility of establishing State grades of peanuts, and of forming an organization of peanut growers to meet yearly at Suffolk, and to serve such purposes as market conditions may demand.

MARKET QUOTATIONS.

Daily Market News Service.

A daily market wire service for early and late Irish potatoes, sweet potatoes, cantaloupes, watermelons, and apples, has been maintained this year in coöperation with the Federal Bureau of Markets. Twenty-

one thousand nine hundred and thirty-four bulletins have been mailed from the Elizabeth City office to early Irish potato growers and shippers, 21,100 bulletins from the Laurinburg office to cantaloupe and watermelon growers and shippers, 13,444 bulletins from the Elizabeth City office to sweet potato growers and shippers, and 8,210 bulletins from the Waynesville office to the growers and shippers of late Irish potatoes and apples. The newly established daily market news service operated at Waynesville by this Division, in coöperation with the Federal Bureau of Markets, is bringing for the first time news of general market conditions to the small growers of Irish potatoes and apples scattered through the mountains of Western North Carolina. Such reports are especially valuable in keeping small farmers informed as to the amount of shipments from competing producing sections, numbers of cars arriving on leading markets, and the prices paid each day on those markets. All of our price investigations show the necessity for such a wire service, that is, if production is to be encouraged.

The Weekly Price Report.

The Weekly Price Report now covers prices upon corn, oats, wheat, cowpeas, soybeans, Irish potatoes, sweet potatoes, cabbage, apples, butter, eggs, poultry, cheese, hogs, cotton, cotton seed and cotton-seed meal. Seventy-six thousand seven hundred and ten Weekly Price Reports were mailed out during the last year. In addition to keeping farmers and merchants informed of prices prevailing in markets in this and other states, the Weekly Price Report serves the special purpose of giving information to railroads which are interested in promoting immigration into this State.

A Monthly Market Review.

A monthly review of North Carolina markets will be published later in the year. These reviews will be based upon special reports of prices received by producers in different sections of the State. The purpose will be to obtain and distribute information of prices producers are receiving, the prices they are holding for, and to publish this and similar information from other states to the extent that they will coöperate in following a similar system of obtaining information from producers.

In the United States as a whole, market quotations have been obtained from buyers, and generally published by buyers. In Copenhagen butter prices have been published by producers. Manufacturers in the United States have found it to their interest to publish information of the prices at which they sell their products rather than to rely upon buyers. They have established special committees with a paid secretary to collect and distribute information from and to the membership. Even when such committees do not fix prices, their united action helps to crystallize sentiment in favor of maintaining prices.

All price investigations conducted in this State this year, as well as in previous years, show as wide differences in prices as those which have been published in the Weekly Price Report. To illustrate, seven counties report that producers are receiving on November 1st $1.20 per bushel for cotton seed, one county 70 cents, one 80 cents, and one 96 cents, and the average for the State, 27 counties reporting, is $1.07 per bushel. Some farmers in North Carolina reported to be holding cotton seed for an average price of $1.33 per bushel.

The discrepancy in corn prices in different sections of the State is still greater. According to special reports, corn on November 1st was selling in Iredell County at $1.15 a bushel, in Burke, Chatham, Henderson, and McDowell counties at $1.25 a bushel, and in thirty counties for an average price of $1.71 a bushel. Thus, in many places farmers are selling much below the market price of Western corn delivered in this State, as shown by the Weekly Price Reports and letters just received. Later, in the spring, North Carolina corn will sell for as much or more than the price of Western corn delivered. No. 2 white Western corn would cost $2.29 to $2.32 put down in Raleigh, N. C., and more or less in other North Carolina towns, according as the freight rate to those towns is more or less than fifteen cents a bushel, the rate from Chicago to Raleigh. Undoubtedly, as soon as farmers begin selling there will be a slump in prices in every town in the State where a surplus of corn is produced. Merchants cannot sell much, if any, corn this fall. Therefore, what they buy will be bought at a discount and there always will be some farmers who are forced to sell at some price, especially until they organize credit unions to take care of their temporary needs.

ORGANIZATION FOR MARKETING.

Potatoes and Apples.

This fall a small organization of growers of late Irish potatoes and apples was formed in Haywood County, and incorporated under the coöperative law of the State as the Mountain Growers Exchange of Western North Carolina. As soon as the Exchange began to operate under the guidance of a manager furnished by this Division, the price of potatoes rose from eighty cents to a dollar a bushel, and later when the Exchange raised the price to $1.20 a bushel, local buyers raised their price accordingly. At the same time buyers in Hendersonville were only paying one dollar a bushel. Thus the Exchange had the effect of raising the price of potatoes in the Waynesville section fifty cents a sack to both members and nonmembers.

While the newly established market news service will help inform the small grower of market conditions, organization is necessary to enable him to profit by such knowledge. The Exchange has adopted

the United States potato standard, and has graded and sold their potatoes according to this standard. The Exchange has secured two government contracts. In fact, the demand from different markets at good prices has been much greater than the supply of potatoes.

The Carolina Potato Exchange had a successful season in spite of the bad condition of the crop. The manager, loaned by this Division, obtained exceedingly good prices for the members, considering the fact that late frosts and heavy rains at digging time made the crop of such poor quality that a large part of it was too small to grade. Because of the Exchange, non-members received much higher prices than they otherwise would have. Buyers made tempting offers to the members of the Exchange and paid such high prices for a poor grade of potatoes that it was with difficulty that any standard of grades was maintained at all.

A State grading law is needed to help the marketing exchanges and North Carolina growers generally. If we allow other states to get ahead of us in the adoption of the grading law recommended by the Federal Bureau of Markets, our growers are going to be at an increasing disadvantage in selling their less well graded stock in northern markets.

A whole bulletin could be written to show the discriminatory practices of buyers to break up organizations of producers. We have recommended to the United States Food Administration the adoption of the following regulations to govern country shippers in keeping with the Federal Food Control Act:

1. No farm products shall be bought at a flat rate. The price shall vary according to the grade. It shall be considered an "unjust" and "discriminatory" practice for any shipper to pay a farmer the same price for a poorly graded product as for one properly graded, according to the standards accepted by the Food Administration. In the case of farm products in which the United States Department of Agriculture has worked out grades by Congressional enactment or at the request of the Food Administration, the price shall vary according to the scale of differences prevailing upon ten of the leading consuming markets in the United States for the week previous.

2. No shipper shall discriminate between individual farmers in the same locality or between farmers in different localities in the amount paid for the same grade of produuct at any given time; provided, that differences only to the amount of differences in the rates of transportation shall be allowed.

3. No shipper shall pay a higher price than the market price either for the purpose, or with the effect, of crushing competition.

4. The ownership by shippers of any facilities for transportation which are used by competitors constitutes a discriminatory practice or privilege which is forbidden all licensees under the Food Control Act.

5. No shipper shall make any "unjust, unreasonable, discriminatory, and unfair" charge, commission, profit, or price.

6. Any shipper may authorize agents to sell upon commission. Agents so authorized shall not diectly or indirectly buy upon their own account, nor shall any concern in which said agents have any interest buy such products; provided, the shipper may authorize agents to buy such consignment at an agreed upon price. When so bought, the agent shall be allowed no commission.

The weakest part in the whole system of distribution is at the country shipping points, but the hardest to remedy because of the number of such points. Any food control act which does not effectively regulate the conditions under which farmers sell their produce, cannot hope to materially increase production. The Food Control Act gives the greatest opportunity for the government to lay down such conditions as shall make possible the development of permanent marketing machinery among farmers, such as shall increase prices to producers, and correspondingly increase the production, lower the cost of distribution, and reduce the cost to consumers. The trucking capacity of this and other States could be greatly increased if a more stable market and fairer conditions of marketing could be assured, as outlined by the regulations proposed. A State grading law and a law to regulate and license all country shippers should be enacted if living conditions for farmers to organize are to prevail.

Cotton.

The Edgecombe Cotton Exchange organized in the fall of 1915, sold 900 bales of cotton for its members last year. This Exchange has been a very effective help in inducing buyers on the local market to buy cotton according to the grades of our State graders. The excellent warehouse facilities and the grading office at Tarboro, which are both at the disposal of this organization, give it the necessary business equipment to do the very best work. However, the Exchange finds great difficulty in securing bids on cotton. It has not found the leading cotton buyers of the State willing to do business with the organization. This is a difficulty which the wheat farmers of the West had to meet and overcome in organizing farmers' elevator companies. This Exchange should be a model for farmers to follow at each cotton market center in the State. Especially now when the export cotton business has been cut down and the domestic mill business is greatly increased, there is a supreme opportunity for the cotton farmers of this State to develop cotton selling organizations along lines similar to the Edgecombe Cotton Exchange. The railroads are giving the necessary warehouse storage in transit privileges to make possible the concentration of sufficient cotton at one place and its classification in large-enough even-running lots, which should be of interest to North Carolina mills. When, during the war, economy in transportation must be realized, it should be easier to induce our mills to buy North Carolina cotton in so far as the right staple is available. A circular has been published to show the mills

where cotton of different staples can be found, and an offer made to put mills in touch with growers and shippers of cotton and to furnish them samples. As a result some business with the mills has already been developed by the cotton grading offices.

Hogs.

In the preliminary survey of hog raising, it has been found that many counties have sufficient hogs to ship in carload lots to Richmond, Baltimore and Jersey City markets, or to local packing houses. With relatively low local prices of pork, there has been little encouragement to increase its production. The services of a specialist in hog and grain marketing have been secured to begin work on December 1st. Shipping clubs will be organized wherever there are sufficient hogs or grain to ship in carload lots. When North Carolina farmers realize that the world's markets are open to them, they will breed better hogs, and in the peanut section harden them, according to the methods advised by the Animal Husbandry Division, so that they may obtain the top of the market. Hog producers will be put in touch with growers having a surplus of corn.

COTTON GRADING AND WAREHOUSING.

The Commissioners of eight counties this year made the necessary appropriation to secure the cotton grading service, which is being operated in coöperation with the Federal Bureau of Markets. Cotton this season has been graded in the grading offices located at Raleigh, Lumberton, Clinton, Wilson and Tarboro, for farmers and buyers in the eight counties as follows:

	Bales Graded for	
Counties	*Farmers*	*Buyers*
Robeson	5,219	226
Bladen	1,011	94
Wake	764	148
Onslow	591	
Wilson	1,816	162
Edgecombe	2,906	792
Pender	287	
Sampson	1,884	1,020
Total	14,478	2,442

Last season during the year ending June 30th, about 65,000 bales of cotton were graded for about twenty-five thousand farmers in twenty-two counties. The samples from which the grades are determined are drawn by the ginner after the bale is ginned and mailed to the nearest grading office. The grading service shows farmers that a large part of their cotton is above middling, on an average one-third. With each grade certificate the farmer is mailed a statement of just how many points on or off middling his cotton grades, and how much this will

amount to for the whole bale. From this the farmer who knows current quotations can figure the price of his cotton.

The grading service is increasingly commanding the support of cotton buyers. Two thousand four hundred and forty-two bales of cotton were graded for cotton buyers this year. Buyers, as well as farmers, are put in touch with cotton mills which may be interested in purchasing a particular grade and staple of cotton. In Sampson County much more cotton has been graded this year than last, in the main because the grading office has been located in the county. This has permitted the grader to come into closer contact with farmers, buyers and ginners. This, especially, until farmers have been educated to the value of the grading service, seems to be the most desirable method, and should be followed, as far as funds permit, until a law is secured which shall require all ginners to be bonded and paid for giving a responsible sample and weight of each bale ginned.

Last season about ten thousand bales of cotton were graded for twenty-five cotton mills, and this season 1574 bales have been graded to date. The interest of the mills in sending in the samples is to learn whether the samples represent the cotton according to grades contracted for. In some cases, our graders help in the settlement of disputes between the mills and cotton buyers. Our interest in grading mill cotton is (1) in determining to what extent mills obtain the grade of cotton they think they purchase; (2) to learn the price paid by mills for a given grade of cotton. The latter information will enable us to determine the difference between producers' and consumers' prices for the same grade and upon the same date. This will give us data for a bulletin upon a subject which has not yet been covered.

We have coöperated with an expert furnished by the Federal Bureau of Markets, in studying the warehouse needs of the State and in informing warehouse operators of the advantages of the United States Warehouse Act. With ample and well distributed licensed bonded warehouses storing cotton classed by licensed graders, farmers should be able as never before to save loss from exposure, obtain reasonable credit, and to organize to sell on grade when and where the best prices prevail.

ORGANIZATION AND SUPERVISION OF CREDIT UNIONS.

During the last year seven credit unions have been organized, making fifteen organized to date. The membership of the credit unions has increased from 285 to 527, the depositors from 55 to 181, and the total resources from $7,471.42 to $19,515.65, the number of borrowers from 65 to 136, and the amount loaned from $5,773.73 to $14,518.14. The main results achieved by these new coöperative banking institutions are (1) encouragement of savings among young and old; (2) borrowing from banks at five per cent interest; (3) loans to members at six per cent, and (4) encouragement of coöperative cash purchases of supplies.

Junior Savings Clubs have been organized in connection with several of the credit unions. The Superintendent of Schools of Mecklenburg County has approved of the plan which we have worked out for collecting savings from the children through school teachers. This plan will be put in operation this fall in the schools adjoining credit unions in several counties. It is frequently found that the older folks become interested in the credit unions through the interest of the children in saving.

The three credit unions for which we have data, Carmel, Lowe's Grove and Drowning Creek, calculated that they saved all together $2,209.66, by paying cash over what the supplies would have cost if bought on time. The approval of the Governor of North Carolina of farmers organizing credit unions and of their depositing their savings in credit unions or banks, should encourage farmers to take hold of this work of gathering savings in their own coöperative banks and of developing coöperate credit in the country at low rates of interest.

LONG TIME LOANS.

Since the Federal Land Bank opened for business in February, 1917, this Division has forwarded applications for loans amounting to $2,820,901, or nearly half of the total loans applied for by North Carolina farmers. North Carolina ranks first in this land bank district in the amount of loans applied for, in the total loans approved, and in the amount of loans granted up to October 31, 1917, as indicated in the following report, just received from the Secretary:

	Total Loans Applied for.	*Total Loans Approved.*	*Total Loans Closed.*
North Carolina	$6,132,419	$2,120,971	$284,615
South Carolina	5,320,787	1,413,718	271,065
Georgia	2,525,287	488,205	40,700
Florida	5,790,307	760,995	32,900
Total	$19,768,800	$4,783,889	$629,280

On October 31st loans amounting to $193,250,945 have been applied for to the twelve land banks in the United States. North Carolina ranks eleventh in the amount of loans applied for in the United States. The eleven states applying for the most loans under the Federal Farm Loan Act have applied for loans as follows: Texas, $19,167,223; California, $14,887,389; Montana, $9,660,919; North Dakota, $9,155,550; Washington, $9,044,889; Kansas, $7,347,477; Nebraska, $7,137,445; Colorado, $6,563,242; Mississippi, $6,352,977; Oregon, $6,340,778, and North Carolina, $6,132,419.

From the addresses given by the President, Mr. F. J. H. von Engelken, and the Secretary, Mr. Howard C. Arnold, at the State Farmers' Convention, it was evident that not only the activities of this institution are bringing a large amount of new capital for the use of the farmers of

this State, but also the methods, according to which the loans are granted, are so much in sympathy with the purposes of the agricultural institutions of this State, that this loan agency will be a most powerful factor in the development of the agriculture of this State. Loans are to be granted upon approved plans of farming at a low rate of interest, five per cent, not to speculators, but to farmers who farm their own land, not to landlords who do not operate their own farms, rather to the tenants who have some capital, the landowner to be encouraged to sell to the tenant and to take a second mortgage.

Undoubtedly, there is room for coöperation in this, as in other States, between this Division and the Land Bank to develop second and third mortgage facilities in order to encourage settlement and development of raw lands. In California scientific settlement of lands is being encouraged by this means. A just system of financing the settler, of helping him to organize with others in buying supplies, and in marketing crops, and of furnishing him export agricultural advice to insure a profitable settlement of lands is to take the place of the old system of exploitation, failure, and arrested development.

PUBLICATIONS.

During the last year new publications covering the work of this Division have been issued as follows:

Daily Market News Service Bulletins.
Weekly Price Reports.
One U. S. Department of Agriculture Bulletin, 476. A Study of Cotton Market Conditions With a View to Their Improvement.
One Extension Cotton Grading Circular.
Two Extension Credit Union Circulars.
Two Farmers' Market Bulletins.

Respectfully submitted,

WM. R. CAMP,

Chief, Division of Markets and Rural Organization.

REPORT ON DRAINAGE.

To the Director:

I herewith submit report on Drainage for the fiscal year ending June 30, 1917.

The work of drainage investigations in North Carolina has been conducted chiefly along the same general lines as in previous years, with perhaps an increase in the number of experimental studies. The work has become established and more tangible results are being obtained. The work is coöperative, and the division consists of two drainage engineers, F. R. Baker, assistant drainage engineer of the North Carolina Department of Agriculture, and H. M. Lynde, senior drainage engineer, of the Office of Public Roads and Rural Engineering, U. S. Department of Agriculture, together with such collaborators and assistants as may be needed from time to time.

In general, the following investigations have been conducted:

1. The making of the requisite preliminary surveys for the preparation of plans for tile drainage systems, and giving the necessary supervision to the construction of the recommended works, for such experimental tracts selected.

2. The collection of data relating to the proper spacing and depth for underdrains in the various kinds of soil by studying the efficiency of such drains already installed, and by the installation, where practicable, of purely experimental underdrainage systems.

3. The study of the methods of drainage of hillside lands, including the investigation of the slopes, arrangement, spacing, and best methods of constructing terraces and drains.

4. The collection of data to show the proper run-off for which provision should be made in designing drainage systems.

5. The making of preliminary examinations of drainage districts desiring to undertake drainage improvements, for the purpose of determining approximately the feasibility of drainage and the general plans to be followed, and to take up any similar line of investigation that has been mutually agreeable.

Specifically the work for the past year may be divided under the following headings:

1. Farm Drainage.
2. Runoff Data on Drainage Canals.
3. Preliminary Examinations and Reconnaissance.
4. Study of Efficiency of Underdrains on Cotton Valley Farm.
5. Experimental Maintenance Work on Drainage Canals.

FARM DRAINAGE.

During the past year, preliminary surveys, designs and reports for tile drainage systems have been made on twenty-seven farms in eighteen counties, comprising a total area of about 1,200 acres. Portions of the

systems designed have been installed on some of the farms. The location work on Cotton Valley Farm, Edgecombe County, was completed and this farm now has a 200-acre field completely underdrained by tile ranging from 60 to 100 feet apart where needed, with random lines in other portions. All open ditches, which were a continual care and expense are now done away with and better drainage is assured.

Preliminary examinations, surveys, designs, and reports were made on four farms in four counties comprising a total area of about 1,300 acres for open ditch systems or the prevention of overflow.

Several farms have been visited for the purpose of giving assistance in the location and construction of terraces to prevent hillside erosion.

RUN-OFF DATA ON DRAINAGE CANALS.

The gauging stations for the determination of run-off have been continued on Toisnot Swamp Canal, Wilson County, and on Third Creek Canal, Iredell County. The records of daily gauge heights on Third Creek are complete from March 17, 1913, to date; those on Toisnot Swamp from March 29, 1914, to date. A paid observer is employed at each place.

Current meter readings of the flow in the canal at the station on Third Creek have been obtained from time to time, at different stages of the water by Mr. J. P. O'Quinn, gauge observer. Thus an estimate of the amount of water carried by the canal for the different gauge heights may be obtained. A run-off curve for various stages up to ten feet has been plotted.

Preliminary Examinations and Reconnaissance.

Three examinations of a preliminary or reconnaissance nature have been made and reports issued covering a total area of 18,500 acres. A reconnaissance survey was made of the land in the vicinity of Big and Little Alligator Swamps in northwestern Brunswick County.

Study of Efficiency of Underdrains on Cotton Valley Farm.

Arrangements were made with George A. Holderness, owner of the Cotton Valley Farm, near Tarboro, Edgecombe County, to conduct experiments on the tile drainage systems installed under the supervision of this division. Two systems, each with a separate outlet, were selected. One system, draining about sixteen acres, has tile drains uniformly spaced 100 feet apart at an average depth of 3 feet in a black sandy loan soil underlaid mostly by sand. The other system draining about forty-six acres has tile drains uniformly spaced 60 feet apart over most of the area, at an average depth of 3 feet in a stiff clay soil.

Two concrete weir boxes, one at the outlet to each system, have been built, and the discharge or run-off from the underdrained areas is

measured by 90-degree triangular weirs. Continuous records of the heads on the weirs are obtained by automatic register clocks which need attention but once a week to change charts and to rewind clocks. Daily rainfall records are obtained by a rain gauge located in the center of the two drainage areas, which adjoin on opposite sides of the outlet canal. From the measured discharge from the two drainage systems, it is hoped to obtain some valuable data as to the amount of run-off to be provided for in the design of underdrainage systems in two types of soil. By keeping continuous records of both the rainfall and the run-off, it is expected that some relation may be obtained between the two.

In order to study the action of tile drains in lowering the ground water level, about 120 observation wells, 3½ feet deep have been installed between the tile lines. Measurements of the water level in these wells are made two or three times a week and oftener in wet seasons.

Mr. W. J. Wickham, who helped to install the drains on Cotton Valley Farm, has been employed since November, 1916, to look after these records. It is hoped to continue the observations for another year at least.

Experimental Maintenance Work on Drainage Canals.

Under ordinary circumstances, a new canal, if properly constructed, should require little attention or repair for two or three years, but after that, it should be given annual attention. The removal of weeds, silt, logs, trees and other obstructions from the canal annually, then becomes a necessity to keep it up to its original efficiency. The opening up of new land in the district necessitating the construction of farm ditches emptying into the main canal, requires that some attention be given these outlets, so that they will not cave or permit the carrying of loose or eroded dirt into the main waterway, causing sand or silt bars to form. In many of the districts in the Coastal Plain section, the flow during a large part of the year is small and the water tends to follow a winding course over the wide bottom of the canal. It seems advisable to confine this water to a straight, narrow, low-water channel, leaving the larger cross-section of the ditch to take care of the flood water.

In the Piedmont or hilly section of the State, the deposition of sand in the main canal brought down by its swift flowing tributaries becomes a serious menace. The breaking down of banks at weak and low places, and on the outside of curves, at flood stages, causing the water to rush over cultivated fields, thus ruining the land either by too much water or the deposition of sand, needs attention also.

For the purpose of studying the best methods and cost of maintenance of drainage canals in this State, the Office of Drainage Investigations, U. S. Department of Agriculture, S. H. McCrary, Chief, expended approximately $1,200 in the spring of 1917. This work was done under the direction of the writer, assisted by Mr. Guy L. Smith, junior drain-

age engineer, who had immediate charge of the field work. The districts selected for these experiments were Back and Jacob Swamps, Robeson County, in the Coastal Plain, and Third and Fourth Creeks, Iredell County, in the Piedmont Section.

The work on Back and Jacob Swamps was carried on during the months of March, April, and May, and that on Third and Fourth Creeks in June, continuing into July. The object of the work was to put selected stretches of these canals in good order and to keep them in this order with a minimum expenditure annually. It is the intention to carry on this maintenance work each year.

On Jacob Swamp, a section approximately 2 miles long, and on Back Swamp, a section 1¾ miles long, were selected. Before the work was started, a survey was made and cross-sections of the canal prism taken every 100 feet, all referenced to a base line along the side of the canal which may be easily picked up each year. The work on Jacob Swamp consisted in clearing the banks, the removal of all weeds, sand bars, logs, trees and other obstructions from the canals, and the excavation of a low-water channel and the construction of outlet works to all side ditches. The work on Back Swamp was not so extensive, since no weeds were growing in the bottom of the canal and very little brush on the banks. It consisted in the removal of sand bars, logs, trees and other obstructions and the construction of outlet works to side ditches. Several types of outlets were constructed, the idea being to devise cheap but efficient methods of letting water into the canal, using as much local material that every farmer has access to as possible. A complete record of all the details affecting the work and cost were kept. From 10 to 12 men on an 8-hour basis, were employed on Back and Jacob Swamps. Approximately $650 were expended for labor and material on Jacob Swamp and $200 on Back Swamp.

The work on Third Creek, Iredell County, consisted principally in repairing breaks at low and weak places in the banks by the construction of wooden retaining walls along a stretch of about 2 miles at the upper end of the district. The work on Fourth Creek consisted in repairing a particularly bad opening in the bank about 500 feet long, located on the land of Mr. F. H. Daniels. Approximately $240 were expended for labor and material on Third Creek and $140 on Fourth Creek. By watching the action of these walls under the most severe conditions, it is hoped to devise some cheap and permanent methods of maintenance.

Respectfully submitted,

H. M. Lynde,

Senior Drainage Engineer.

STUDIES ON RESISTANCE OF TOMATOES TO BACTERIAL WILT.

By E. E. STANFORD.

Studies have been conducted at this Station for several years upon wilt diseases of tobacco and tomatoes, both of which are caused by a bacterial organism, *Bacterium solanacearum* E. E. S. Since this organism is very generally the cause of a tomato wilt disease within North Carolina, reports of its presence in thirty-nine counties having been received, an attempt was made to learn if certain commercial varieties of tomatoes possessed any marked resistance or natural immunity to wilt. While only negative results have been secured and there appears to be no hope of successfully combating this disease by seeking for natural resistance and immunity, the results are recorded in the belief that they are of value to others who may undertake experimentation upon the same disease.

During the season of 1914, seven varieties of tomatoes wre grown in a field near Creedmoor, N. C. A part of this field was being used in studies on the effect of rotation and of the employment of certain cropping systems upon the control of tobacco wilt. The soil was believed to be thoroughly infested with the wilt organism, as judged by the prevalence of wilt in previous crops. The following tabulation presents the results of this season's results on wilt resistance.

TABLE 1. TOMATO WILT RESISTANCE TESTS AT CREEDMOOR, N. C., IN 1914

Variety	No. of Plants	Condition	
		Healthy	Wilted
Louisiana Wilt Resistant**	26	10	16
Texas Belle	26	1	25
Stone	28	1	27
Golden Queen	23	8	15
Lorillard	25	14	11
Bonny Best	25	1	24
Livingston's Globe	45	3	42

It is evident, first of all, that the number of plants used in this test was too small to serve as a convincing demonstration. It will be noted, however, that a smaller proportion of the variety, Lorillard, succumbed to wilt than of the other varieties. On the assumption, therefore, that this indicated a degree of resistance, seed were saved from the choicest fruits of the plants which remained healthy. These, together with seed from a number of other varieties, were used for a more extensive test

*Mr. E. E. Stanford was connected with these investigations until his resignation from the Station, March, 1917. This report was prepared with Mr. Stanford's permission, by Frederick A. Wolf, Botanist, North Carolina Agricultural Experiment Station.

**This variety is resistant, in Louisiana, to wilt produced by Fusarium sp.

during the following season. The field used in this test was located at West Raleigh. Tomatoes had been grown in this field during 1914, and serious losses from bacterial wilt had occurred so that the soil was very generally infested.

The results of examination of these plants on two successive dates are brought together in Table 2.

Table 2. Tomato Wilt Resistance Tests at West Raleigh

Variety	No. of Plants	Condition Aug. 25		Condition Sept. 14, '15	
		Healthy	Wilted	Healthy	Wilted
Louisiana Wilt Resistant	71	48	23	19	52
Oregon Wilt Resistant	81	44	37		
Greater Baltimore No. 456	83	51	32		
Stone No. 457	76	53	23	24	52
Duke of York	101	34	67		
Blight Proof	70	35	35		
Lorillard	72	53	24	28	49
Long Keeper	95	29	66		
Redfield	70	41	29		
Stone	87	65	22	43	44
Stone No. 460	95	75	20		
Greater Baltimore	93	79	14	56	37
Stone No. 459	91	83	8		
Prosperity	81	73	8		
My Maryland	88	69	19		
Greater Baltimore	96	85	11	23	73
New Experimental	85	65	20		
John Baer	90	72	18		
Bonnie Best	71	44	27		

It was found during this season, that many of the varieties tested, disregarding wilt resistance, were not suited because of size, texture, color, flavor, or yield to North Carolina conditions. Others made very poor vegetative growth. Consequently, seed from these varieties were not saved for subsequent tests. It was believed to be desirable, however, to study further three varieties, namely: Greater Baltimore, from three sources, Lorillard, and Stone. Seed were, therefore, saved from plants which remained healthy. These were tested together with a number of varieties not previously used, in 1916, at West Raleigh.

With reference to this season's tests, it may be said that the three varieties whose seed were saved from the 1915 crop showed no increased resistance nor did the varieties not previously tested appear to possess any resistance.

In conclusion, it does not appear that resistance, in tomatoes, to bacterial wilt can be augmented by seed selection from plants which remain healthy to maturity.

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NORTH CAROLINA

AGRICULTURAL EXPERIMENT STATION

CONDUCTED JOINTLY BY THE

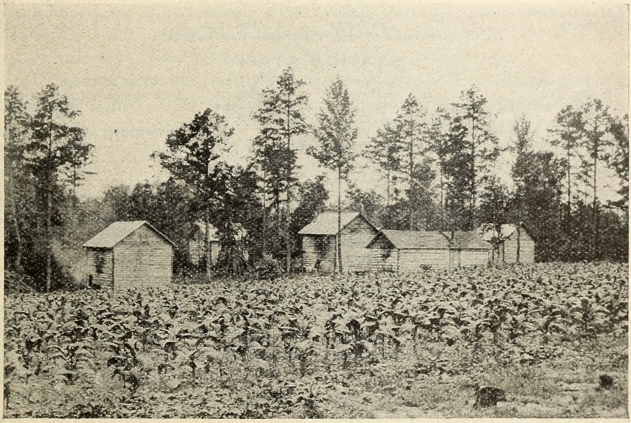
STATE DEPARTMENT OF AGRICULTURE

AND THE

N. C. STATE COLLEGE OF AGRICULTURE AND ENGINEERING

RALEIGH AND WEST RALEIGH

DIVISION OF AGRONOMY



TYPICAL FIELD OF BRIGHT TOBACCO AND CURING BARNS

Tobacco Culture in North Carolina

By E. H. Matthewson and E. G. Moss

THE NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION

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N. C. STATE COLLEGE OF AGRICULTURE AND ENGINEERING

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The members marked with * are members of the Joint Committee for Agricultural Work, and the Station is under their direction.

[1]In cooperation with the U. S. Department of Agriculture, States Relation Service.

[2]In cooperation with the U. S. Department of Agriculture, Bureau of Soils.

[3]In cooperation with the U. S. Department of Agriculture, Bureau of Animal Industry.

[4]In cooperation with the U. S. Department of Agriculture, Office of Public Roads and Rural Engineering.

TOBACCO CULTURE IN NORTH CAROLINA

By E. H. Matthewson and E. G. Moss[1]

The cultivation of tobacco in North Carolina began with the earliest pioneers, constituting at first a frontier from the Virginia settlements. The first permanent settlement was made by Virginians about 1660 on the Chowan River. As in Virginia, therefore, tobacco growing in North Carolina began on the river lands of the coast country, but settlers constantly made way westward into the upland sections, where it was found that a more satisfactory quality of tobacco could be produced, and its cultivation was finally completely abandoned on the river low-grounds.

In the earlier days, and up to about 1870, the tobacco grown in North Carolina moved to market largely through the earlier established Virginia markets, Petersburg, Clarksville, Danville, and others. The growers would prize the tobacco into stout hogsheads and roll them many miles to these distant markets, the trip often taking several days. Fayetteville, at the head of navigation on the Cape Fear River, and similar towns on the Neuse and the Roanoke, served as shipping centers for considerable quantities of North Carolina tobacco. From these points the tobacco was floated down to tide-water, reaching ocean navigation at such towns as Wilmington, New Bern, and Edenton.

The type of tobacco produced in North Carolina has always been similar to that produced in the border counties of Virginia. Up to the time of the War of Secession, the development was toward a light red or mottled tobacco of the French export type and suitable also for fillers and wrappers for plug, which was the popular form in which tobacco was used in domestic consumption prior to the war. The flavor and odor of smoke was objectionable on these types, and they were therefore largely air-cured or fired but lightly—sufficient to prevent damage from mold or "houseburn."

The first development toward the modern system of flue-curing was in the use of charcoal as a source of heat, which is practically smokeless. Numerous piles of the glowing coals were scattered over the earth floor of the curing barn. Blackened spots of soil indicating the location of coal pits may still be seen here and there on the farms of the older tobacco districts of the State. Many men in North Carolina of the older generation now living have burned charcoal and used it in curing tobacco.

MODERN DEVELOPMENT

The really important development of tobacco growing in North Carolina to its essentially modern basis has come almost entirely since the

[1]In accordance with an agreement between the N. C. Department of Agriculture and the Bureau of Plant Industry of the U. S. Department of Agriculture, this bulletin has been prepared by E. H. Matthewson of the Federal Department and E. G. Moss of the Federal and State Departments.

Civil War. A number of factors have contributed in making the development of the past fifty years possible. Among the more important of these influences may be mentioned:

1. The introduction of the modern system of curing by means of flues with furnaces fed from the outside of the barn, a much easier method; the heat could be better controlled and the cures were much more uniform and satisfactory.

2. The introduction of commercial fertilizers, enabling the grower to greatly increase his yield and often improve the quality of the tobacco and therefore the profit from its production. The soils suited for tobacco were naturally rather infertile. Before the introduction of fertilizers the cultivation of tobacco was of necessity largely confined to freshly cleared land. Fertilizers, however, made it profitable to cultivate old as well as freshly cleared land, thereby rendering more readily possible the great expansion that has followed.

3. About this time, also, in the late '60s and '70s of the last century, the consumption of smoking tobacco in the granulated form for pipe and cigarette began to increase greatly, thus steadily enhancing the demand for the North Carolina type of tobacco. The Dukes, Blackwells, and Carrs of Durham were pioneers in introducing and stimulating the demand for these types. A little later the machine-made cigarette still further added to the demand for the higher priced and more profitable grades of bright flue tobacco.

A fourth influence in stimulating the production of this type was the concurrent rapid expansion in the foreign demand. Flue-cured tobacco is one of the mildest and most beautiful in appearance among the tobaccos of the world. It is pleasantly aromatic and is perhaps unrivaled in general popularity and all-around adaptability for all purposes except standard cigars and snuff. It is widely used both in the United States and abroad for pipe smoking and cigarettes, and in domestic trade is also extensively used for chewing in the form of plug.

EXTENSION OF PRODUCTION

In the '80s of the past century the extension of tobacco-producing area was mainly toward the west. At one time Asheville and Marshall in Buncombe and Madison counties, respectively, were quite important tobacco markets. The Census of 1879 credits the State with a production of 26,986,213 pounds of tobacco and that of 1889 with a production of 36,375,258 pounds.

But it was during the succeeding decade of the '90s that the most remarkable expansion of production took place, this time into the coastal plain section of the State, to the east and southeast of Warren, Franklin, and Wake counties. The spread of production was very rapid, so rapid, in fact, that the 1899 census showed a production of 127,503,400 pounds, an increase for the decade of more than 350 per cent. This period of expansion culminated in the great crop of 1903,

after which there was considerable retrogression and fluctuation, particularly in the new area of the coastal plain, or New Belt, as it was called, due to lower prices for tobacco and higher prices for cotton, causing considerable shifting of acreage.

The crops of 1913, 1914, 1915 again showed marked tendency toward expansion, especially in the New Belt section, the crop of 1915 being probably the largest ever grown there up to the time of the present writing, 1916. This expansion of the past few years came somewhat as a sequel to the reduced crops of 1911 and 1912, due to unfavorable seasonal conditions, but more largely to the tendency to expansion in smoking tobacco and cigarettes in the home trade and to a large expansion in foreign demand, particularly in the Orient. Prices were high, particularly for smokers and cutters, of which the major portion of the new production normally consists.

POSITION OF NORTH CAROLINA AS A TOBACCO GROWING STATE

The total tobacco crop of the United States in round numbers amounts to about 1,000,000,000 pounds per annum. Of this, the flue-cured type now amounts to about 300,000,000 pounds or approximately 30 per cent, and is produced almost entirely in the contiguous territory of southern Virginia, northern and eastern North Carolina, and northeastern South Carolina. North Carolina produces upwards of three-fifths of the flue-cured or bright type, and among the States stands second in total quantity of tobacco produced, being exceeded only by Kentucky.

In manufactured tobacco North Carolina is preëminent, the output being upwards of 100,000,000 pounds annually. Winston and Durham are among the very largest tobacco manufacturing centers in the country, and Reidsville is also a manufacturing center of importance.

IMPORTANCE OF TOBACCO GROWING IN THE STATE

The annual value of the tobacco crop of North Carolina is from $15,000,000 to upwards of $25,000,000. Among the other crops of the State, cotton alone brings the farmers more ready money. According to the Census of 1909, tobacco was produced in quantities of commercial importance (250,000 lbs. or more) in 39 of the 100 counties of the State. In most of the Old Belt counties tobacco was the major money crop, and it ranked second to cotton only in most of those of the New Belt. In the Old Belt section of the State cotton is grown but little, while in the new or coastal plain section cotton is nearly always the money crop of first interest and importance; but even here there are several counties in which tobacco is about equal in value to cotton or is a fairly close second.

In the table below are listed the counties of the State in which tobacco was produced in quantities of 250,000 pounds or more. The figures were taken from the census report of 1909.

Production of Tobacco in North Carolina in 1909 by Counties. The 13th Census Figures are the Basis.

County	Old Belt Section		New Belt Section	
	Acres	Pounds	Acres	Pounds
Pitt			14,130	10,973,950
Rockingham	14,701	8,279,194		
Granville	13,645	7,073,646		
Stokes	11,944	7,694,827		
Wilson			11,285	7,092,890
Nash			11,438	7,070,686
Person	11,858	6,904,306		
Caswell	11,196	6,435,570		
Greene			9,011	6,645,524
Lenoir			8,337	6,588,205
Surry	10,417	5,715,414		
Wake	8,101	4,478,073		
Johnston			5,862	3,960,831
Robeson			4,263	3,773,910
Vance	6,629	3,854,390		
Forsyth	6,290	3,592,237		
Wayne			5,235	3,439,063
Duplin			4,024	3,206,817
Franklin	5,909	2,873,878		
Guilford	5,052	2,798,325		
Edgecombe			4,009	2,637,005
Yadkin	4,431	2,258,606		
Durham	3,424	1,995,807		
Alamance	3,306	1,878,225		
Martin			3,183	1,813,278
Orange	2,936	1,772,103		
Warren	2,632	1,543,378		
Columbus			1,854	1,506,201
Beaufort			1,717	1,347,841
Craven			1,662	1,238,282
Jones			1,304	1,083,943
Onslow			1,229	1,053,769
Davidson	2,019	1,066,331		
Halifax			1,560	924,435
Sampson			1,184	826,358
Davie	1,147	578,431		
Bertie			877	570,356
Chatham	1,110	543,404		
Carteret			291	266,360
Miscellaneous	1,702	815,128	937	643,186
Totals	128,498	72,150,273	93,392	66,442,890

Total production of State in 1909:	Acres	Pounds
Old Belt	128,498	72,150,273
New Belt	93,392	66,442,890
Entire State	221,890	138,593,163

Average yield per acre for State	624.6
Average yield per acre for New Belt	711.4
Average yield per acre for Old Belt	577.0
Difference favor New Belt	134.4

Since the census year (1909) there has been a very decided increase in the tobacco production, particularly in the New Belt section, beginning from 1913. This expansion was stimulated by the high prices paid for tobacco, particularly smokers and cutters. Both the home and foreign demand was expanding rapidly in these grades, in the production of which conditions in the New Belt are particularly favorable. There is also a greater supply of available labor in the coastal plain section, inasmuch as a portion of the labor employed in the major crop, cotton, can be shifted to tobacco if it becomes profitable to do so.

This expansion in acreage and production is forcibly illustrated by comparing the official report of sales of the New Belt markets in the season 1914-15 with those of 1910-11.

Sales, first-hand, in the tobacco markets of the New Belt section of the State for the years shown. Compiled from the official reports collected by the State Department of Agriculture.

Market	Period, August, 1914, to August, 1915—Pounds	Period, August, 1910, to August, 1911—Pounds
Wilson	23,508,093	9,606,800
Greenville	19,639,020	7,469,147
Kinston	16,203,857	6,237,568
Rocky Mount	12,865,270	4,123,954
Farmville	5,838,792	2,023,985
Smithfield	4,248,754	1,452,847
LaGrange	3,493,876	2,052,287
Zebulon	2,842,949	407,394
Snow Hill	2,713,286	1,397,936
Goldsboro	2,678,477	940,544
Williamston	2,536,936	519,171
Warsaw	2,436,343	569,256
Washington	2,509,978	366,366
Fairmont	2,421,857	1,103,305
Robersonville	2,207,131	632,049
Wendell	2,048,956	392,241
Fair Bluff	1,500,319	888,994
New Bern	1,367,078	
Wallace	902,051	
Ayden	722,181	475,863
Spring Hope	877,352	
Clinton	571,715	267,452
Richlands	437,721	716,226
Tabor	267,382	
Fayetteville	236,389	
Mount Olive	265,586	
Whiteville	90,231	
Ahoskie		242,882
Lumberton		178,145
Enfield		169,580
Dunn		84,286
Clayton		43,271
Totals	115,630,680	42,361,459

These figures show that the production in the New Belt section was increased nearly threefold during this brief period of four years, but it should be remembered that the production in this section had been about twice as great at the previous high level of 1903 as it was in this much reduced production of 1910, and the figures well illustrate the marked tendency to fluctuation in the coastal plain section.

On the other hand, the table below illustrated the comparative steadiness of planting and production in the Old Belt section where there are no other important competitive money crops, and where labor conditions do not permit of such ready fluctuation in the area planted. While the table shows considerable increase, when the same two years are compared the fluctuation is nothing like so striking as in the New Belt.

Sales, first-hand, in the tobacco markets of the Old Belt section of the State for the years shown. Compiled from the official reports collected by the State Department of Agriculture.

Market	Period, August, 1914, to August, 1915—Pounds	Period, August, 1910, to August, 1911—Pounds
Winston-Salem	22,748,614	19,942,917
Oxford	8,371,505	6,086,582
Durham	7,787,904	4,518,721
Henderson	7,783,233	4,596,076
Reidsville	5,190,543	5,555,967
Louisburg	4,057,681	2,398,825
Roxboro	3,994,693	5,305,589
Fuquay Springs	3,593,580	628,347
Mount Airy	2,978,432	3,986,872
Apex	2,315,205	1,116,350
Warrenton	2,534,650	1,734,277
Mebane	1,690,819	889,968
Youngsville	1,894,091	832,433
Walnut Cove	1,927,714	
Greensboro	1,905,926	1,355,812
Madison	1,699,132	1,741,667
Burlington	1,659,117	1,924,015
Elkin	1,437,864	
Stoneville	1,368,178	2,175,660
Creedmoor	1,075,628	1,605,644
Pilot Mountain	906,905	444,534
Statesville	667,230	325,526
Varina	245,330	
Vanceboro	176,355	
Leaksville	146,193	287,694
Milton		130,526
Totals	88,156,522	67,487,002
All Old Belt Markets	88,156,522	67,487,002
All New Belt Markets	115,630,680	42,361,459
Total for State	203,787,202	109,848,461

An examination of the table giving production by counties shows that the tobacco crop of North Carolina was produced almost entirely in 39 out of the 100 counties of the State, of which 19 were in the Old Belt and 20 in the New Belt section.

The yield per acre in the New Belt was greater by 134.4 pounds than in the Old Belt. This difference may be regarded as about normal, although it would doubtless be found to fluctuate from year to year. The difference of yield is founded on difference of soil: that of the New

Belt or coastal plain section being deeper and of greater uniformity, and it will stand heavier fertilization without injury to the quality of the tobacco produced. Another factor of importance in bringing about this higher yield in the New Belt section is the practice of harvesting the tobacco by the leaf or priming system, permitting of and making desirable higher topping of the plant.

SOILS OF THE FLUE-CURED DISTRICT

Speaking broadly, the current trade differentiations of the flue-cured producing area into the Old Belt and the New Belt sections indicates also a fairly well defined modification in the character of the tobacco produced in these two sections. The best tobacco soils of both the Old Belt and the New Belt are all light and sandy, but those of the New Belt in the coastal plain are lighter and more sandy as a class than are those of the Old Belt in the piedmont section, and these soils, especially the subsoils, become progressively more clayey as one progresses westward towards the mountains. The lighter coastal plain soils characteristically produce a brighter and paler type of leaf than the Old Belt soils, but with less body and richness.

In the western part of the Old Belt, particularly from about Rockingham County, N. C., and Henry County, Va., the rich waxy filler types predominate, while the colors run in a much larger proportion to mahogany or red. Soil adaptation is a very important factor in the production of a satisfactory quality of flue-cured tobacco. It is an influence of fundamental importance in determining the color of the leaf produced, as well as such other points of quality as fineness, richness, and body.

In general, the soils adapted to the production of the flue-cured tobacco may be described as light and sandy to a depth of 6 to 10 inches, underlain with a sandy clay subsoil of a yellowish orange color.

The white soils produce the brightest tobacco, unless offset by some other factor. The clay of the subsoil is an important factor in giving the leaf richness and body, and it is also an aid in retaining fertility. In the coastal plain section some of the soils are such loose deep sands as to constitute an extreme of the bright tobacco type. Such soils will naturally produce a very bright tobacco, but the leaf is likely to be lacking in body and richness; and the soil itself is at a disadvantage in retaining fertility and is not likely to withstand wet weather well.

On the other hand, the soils of the Old Belt section, more especially in the western part, frequently represent the other extreme of being too clayey and too red to produce anything more than a dark tobacco, although generally the leaf will be rich and waxy.

Between these soil extremes of the New Belt coastal plain section, some of them tending to be too extremely sandy and open, and the clayey soils of the western part of the Old Belt section there is to be found almost every conceivable variation in shade, depth, and mechanical structure.

From a chemical standpoint, bright tobacco soils are rather weak, as is to be expected from their high content of sand or silica, but most of them are very responsive to artificial enrichment by means of fertilizer, manure, and soil-improving crops. The relatively light soils which predominate in the New Belt section naturally are less well supplied with mineral plant food, particularly potash, than are the stronger soils of the piedmont section. However, a soil possessing ideal mechanical and chemical qualifications may be entirely unsuited to tobacco unless it has good natural drainage, as it is ruinous to a tobacco plant to stand for any length of time in a water-logged soil.

FIG. 1. A typical field of flue-cured tobacco in the Old Belt.

In the early days of tobacco culture, before commercial fertilizer came into general use, it was the almost universal custom to plant tobacco on "fresh" or recently cleared land. On such land there is an accumulation of readily available plant food; the tobacco grows quickly, matures and ripens early, and cures well. In the Old Belt, therefore, where much of the soil tends to be too strong and clayey, a given soil perhaps will produce a crop of good color and quality when it is "fresh," but will not do so after it has been under cultivation for a number of years. But in the case of the light soil in the coastal plain section those which have been longer under cultivation are preferable because the "fresh" land will make the leaves too thin and lifeless and the bottom leaves will begin to waste away prematurely.

CROP ROTATION SYSTEM

Aside from the natural character of the soil itself, there is no more important matter for the tobacco grower to consider than the manage-

ment of his fields so that in regular order they will be in the best shape for tobacco at the proper time. Indeed, the character of the tobacco produced will depend quite as much on how the fields have been handled in rotation between the successive tobacco crops as upon the fertilizer used or the cultivation given directly to the tobacco crop itself. A good system of crop rotation is also very essential in order to control some of the diseases to which tobacco is susceptible, such as the Tobacco Wilt, Root Knot, etc. It is impracticable to attempt to lay out any definite rotation plan adapted to the needs of all tobacco farms. For the Old Belt section, however, where there is less diversity in so-called money crops and the area of good tobacco soils is more limited than in the New Belt, a rotation in which tobacco is followed directly by oats or wheat and then by two years of grass would undobtedly be found practicable and suited to the majority of tobacco farmers.

Below are a few possible combinations which might be used in the Old Belt:

First year ....Tobacco
Second year ....Wheat or oats
Third year ....Grass mixture
Fourth year ....Grass mixture
Fifth year ....Tobacco

If this system of cropping supplemented by liberal fertilizing tends to make the soil too rich for the best results with tobacco, the difficulty could probably be overcome by introducing corn into the rotation directly on the grass sod in place of the tobacco, viz.:

First year ....Tobacco
Second year ....Wheat or oats
Third year ....Grass mixture
Fourth year ....Grass mixture
Fifth year ....Corn

There is one objection to this plan, namely, corn frequently harbors large numbers of wire-worms, which makes it difficult to get a stand of tobacco because of the attacks of the wire-worms on the young plants as soon as they are set out.

Another variation would be to follow the tobacco with corn, then wheat or oats, to be followed in turn by two years of grass, making a five-year rotation and putting the tobacco on the grass sod as in the four-year rotation first mentioned, viz.:

First year ....Tobacco
(followed by crimson clover or vetch plowed under.)
Second year ....Corn
Third year ....Wheat or oats
Fourth year ....Grass mixture
Fifth year ....Grass mixture

Where tobacco land is limited, a shorter rotation often is desirable. Tobacco may be followed by wheat or oats and the field left to grow

up in weeds to be turned under the following winter for the next year's tobacco crop. This practice has been pretty generally followed in some sections of the Old Belt, and has given very good results, but it leaves the land idle in the summer to grow weeds and seed the land, which will be troublesome in the next year's tobacco crop.

If by either of the above rotations the land gets too rich to grow a good quality of tobacco, this can be offset very largely by closer planting and higher topping, and by harvesting the tobacco by priming instead of cutting.

In the New Belt there is a greater diversity of money crops. Cotton, peanuts, sweet potatoes, and soybeans may be mentioned, and, among these, cotton would be the one generally preferred because of its ready market and wide adaptability throughout the New Belt section. Legumes are also much less objectionable on the light coastal plain soils, and in many instances a legume could be introduced in the rotation with benefit. In most cases cowpeas would be found more satisfactory for this purpose, or, on the stiffer soils, where they will hold through the winter, crimson clover or hairy vetch might often be used to advantage. When used, these legumes should generally come in the rotation closely succeeding tobacco, so that any excess of ammonia which they might supply could be used up to some extent by the crops intervening before the field comes to tobacco again. On some of the very lightest unimproved soils tobacco will give good results, even if directly following a turned-under leguminous crop, such as cowpeas.

On the stiffer soils of the New Belt the four-year rotation suggested for the Old Belt, namely, tobacco followed by winter oats (instead of wheat), and then two years in herds grass, would be practicable in some cases. If it is desired to put cotton in the rotation, satisfactory results should be obtained by seeding the field to cowpeas as soon as the oats are removed. The peas could either be mowed for hay or turned under, generally the latter when it is desired to improve the soil. The cotton could follow the peas, after which the field could be planted to tobacco again, making a three-year rotation.

There is some objection in certain localities to having cotton precede a crop of tobacco, which may cause the tobacco to have coarse fibers and in some instances perhaps causing it to speck. This trouble in all probability comes from the excessive amount of nitrogen resulting from the incorporation of so much vegetable matter, the residual from the cotton plants consisting of the immature bolls, leaves and stalk. This objection is not general over the New Belt section and could likely be overcome by reducing the nitrogen in the fertilizer under the tobacco and also by increasing the percentage of potash.

Peanuts or sweet potatoes could be introduced into the rotation if desired either in place of or succeeding cotton. Peanuts are a leguminous crop, but since both the vines and the roots are removed in harvesting (unless for grazing hogs), they may be considered an exhaustive rather than an improving crop. Peanuts should not be grown on

tobacco land where there is danger from tobacco wilt. Sweet potatoes leave practically everything on the field except the potatoes themselves, which are principally starch, and this crop, therefore, tends to improve the soil. The vines decay very rapidly and their plant-food content, although rather small, soon becomes available. Here again the rotations mentioned are to be considered only as suggestive, and any number of variations will readily suggest themselves to a thoughtful farmer; but the importance of maintaining a bountiful supply of vegetable matter of a kind which will not be too rich in nitrogen at the time the field comes into tobacco should always be kept clearly in mind when planning the rotation.

FERTILIZERS FOR FLUE-CURED TOBACCO

Bright-tobacco soils as a class are naturally rather infertile, but they are light and friable and of a character to respond readily to fertilizers, particularly in producing a crop of high money value like tobacco. Fertilizers increase the chances of profit from growing bright tobacco in two ways. They greatly increase the yield, sometimes by 100 per cent or more, and if properly balanced they generally improve the quality. Because of the natural deficiencies of bright-tobacco soils and of the special adaptability of commercial fertilizers to bright tobacco there are no other types of tobacco produced in this country on which fertilizers are so freely used except on some of the high-priced cigar-wrapper types in New England and Florida.

A so-called complete fertilizer, that is, one containing each of the materials ammonia (nitrogen), phosphoric acid, and potash is generally needed and the maximum yield cannot be secured unless each is supplied in sufficient quantity.

No general rule as to the proper proportion or balance between these materials can be given and the farmer must exercise judgment in the matter. The best proportions of the three elements are likely to vary considerably on different fields, according to the soil and its state of improvement. As stated, each of these elements has its effect in limiting the yield; but aside from this, broadly speaking, there is a special effect on the quality of the leaf that may be attributed to each element. Too much ammonia, especially if unsupported by a sufficiency of the other fertilizing compounds, particularly phosphoric acid, will make the tobacco coarse, dark, and late in maturing, with a tendency to damage by "red fire" or dead spots here and there on the leaves. Without a sufficient supply of ammonia, however, the tobacco will be small, thin, and poor, although the color may be good. Potash, like ammonia, improves the body of the leaf, and has a decided value in tending to diminish or prevent "diseasing" or "specking." On the light sandy soils of the New Belt section, especially, potash should be applied much more liberally than is now the general custom.

Phosphoric acid may be considered the most generally needed plant-food material throughout the tobacco-growing region under considera-

tion. It not only increases growth, but hastens maturity, and also strongly tends to brighten the color because of its decided effect in ripening the leaf. By reason of this specific effect in thus improving the quality, phosphoric acid should be used liberally in the tobacco fertilizer, particularly on the better improved soils which from an accumulation of nitrogenous materials might tend to produce a dark coarse leaf. On the other hand, some caution should be exercised not to use it in excessive quantities on unimproved very light soils. On such soils there is naturally danger from premature ripening, or "firing," as it is usually called, and such tendency would be increased by an excessive application of phosphoric acid although increasing the ammonia supply would tend to overcome this difficulty with probably increased yield as well. This largely explains why the turning under of a leguminous crop immediately preceding tobacco on such unimproved very sandy soils may sometimes result in positive benefit.

Generally speaking, phosphates (except as just indicated) and potash may be used freely on flue-cured tobacco without injury to the quality, but it requires nice adjustment of the ammonia supply to give the best results. As stated, too little will make a "poor" thin tobacco of small growth, while too much will tend to make the tobacco dark, coarse, and rank smelling. Ammonia in the soil comes almost entirely from decaying vegetable matter or manure and the quantity of the ammonia to be supplied in the fertilizer will depend largely on how much may be expected from these sources in the soil. A crop of 1,000 pounds of flue-cured tobacco to the acre to produce the leaf, stalk, and roots will need to assimilate about 50 pounds of ammonia (equivalent to approximately 40 pounds of nitrogen). On poorly improved sandy soils, generally producing around 600 pounds of tobacco to the acre under ordinary fertilization (say, 500 pounds of 3-8-3 fertilizer to the acre), the yield and quality generally could be improved greatly and the crop made more profitable by using an increased amount of ammonia in the fertilizer. On such a soil it would not be unreasonable to supply in the fertilizer 40 or 50 pounds of ammonia (equivalent to 250 or 300 pounds of 16 per cent dried blood).

Both phosphoric acid and potash are generally needed on practically all the tobacco soils of the flue-cured district, although potash is perhaps of less importance on the stronger soils of the Old Belt section. Neither of these materials is likely to do harm, and any unused portion will not be lost by leaching (except possibly on some of the very deep loose sands of the coastal plain section), but will remain to benefit succeeding crops of the rotation. It would undoubtedly be wise, therefore, to use these materials somewhat more freely than has been customary. In the New Belt this recommendation would apply more particularly to potash because the soils there are relatively more deficient in that constituent, while in the Old Belt, especially on the more clayey soils, phosphates are more urgently needed, although a considerable increase in the potash used, particularly on the lighter soils, would also be desirable.

For general use it would seem reasonable to recommend as a base the use of from 400 to 600 pounds of 16 per cent acid phosphate per acre and in the Old Belt about 60 to 100 pounds of sulphate of potash (analyzing 48 to 50 per cent actual potash (K_2O) or for the lighter soils of the New Belt 100 to 150 pounds of sulphate of potash per acre.

The amount of ammonia to be used with these quantities of phosphoric acid and potash, as indicated above, would depend largely on the condition of the particular field under consideration. In general, it may be stated that proportionately more ammonia can be used profitably on the light sandy soils of the New Belt than on the stronger Old Belt soils. Another feature of importance, particularly on the western part of the Old Belt section, is the time of harvesting and curing. If the crop ripens and is cured in warm weather, say, up to September 10, the tobacco will naturally tend to yellow well and cure bright, as compared with the same tobacco harvested and cured in the cool weather of late September and October. The normal period for curing tobacco in the New Belt is during July and early in August, which are hot-weather months, and this is a factor distinctly favorable to a good bright cure. Tobacco that ripens and cures during hot weather, particularly if the season be rather dry, can satisfactorily utilize a larger amount of ammonia than when the harvest is in cool weather. Wet weather just before the tobacco is harvested is an additional adverse factor.

Increasing the phosphoric acid, as noted above, will tend to brighten the leaf and thus overcome some of the harmful effects of too much ammonia.

In the Old Belt section under average conditions, especially on the stronger type of soils of the western part, probably about 150 pounds of 16 per cent dried blood (or its equivalent in some other good ammoniate) would give approximately the right proportion of ammonia for the minimum amounts of phosphoric acid and potash mentioned above.

The formula would be as follows:

No. 1—	*Pounds*
Dried blood analyzing 16 per cent ammonia	150
Acid phosphate analyzing 16 per cent phosphoric acid	400
Sulphate of potash analyzing 50 per cent potash K_2O	100
Total	650

Such a mixture, while weighing only 650 pounds for an acre of land, would be approximately equivalent to an 800-pound application per acre of a fertilizer analyzing 3 per cent ammonia, 8 per cent phosphoric acid, and 6 per cent potash. If desired, cotton-seed meal (analyzing 7½ per cent ammonia) might be substituted for the blood, using twice the number of pounds.

Possibly a more desirable mixture where the materials are available would be as follows:

Nitrate of soda analyzing 18 per cent ammonia	50 lbs.
Cotton-seed meal analyzing 7½ per cent ammonia	200 lbs.
Dried blood analyzing 16 per cent ammonia	100 lbs.
Acid phosphate analyzing 16 per cent phosphoric acid	400 lbs.
Sulphate of potash analyzing 50 per cent potash	80 lbs.
Total	830 lbs.

The cost of the fertilizer shown in the above two formulas will vary somewhat from year to year, but the first one of 650 pounds will generally be about $10, and the second one of 830 pounds with 15 pounds more ammonia, 5 pounds more phosphoric acid, and 6 pounds less potash, will be about $13. In certain cases, of course, as when the soil had been considerably improved by the use of manure or leguminous crops, even a smaller quantity of ammonia than here mentioned might give better results. In extreme cases, especially when color is an important factor, the ammonia might be omitted altogether. On the other hand, in the case of the lighter types of soils in the Old Belt, particularly in the eastern part of that section, where the lighter types of soil predominate, the proportion of ammonia in the fertilizer generally could be somewhat larger than that shown in the first formula, probably about what is shown in the second formula.

In formula No. 2 about one-fourth of the nitrogen is obtained from nitrate of soda, the remainder about equally from cotton-seed meal and dried blood. For various reasons it is desirable to get the ammonia from more than one source. A small percentage of nitrate of soda can be used without any serious effect on the quality of tobacco; it is readily available and gives the young plant an early start, and afterwards the dried blood and cotton-seed meal become available in the order named. The indications are that the use of some cotton-seed meal in the fertilizer mixture has a tendency to prevent the bleached-out appearances of the leaf caused from a very wet spell and usually spoken of as "sand drown."

Because of the great scarcity of potash during the European War, attention has been drawn to certain home supplies, particularly wood ashes and tobacco stalks. In contemplating the use of either of these materials, it should be remembered that the potash in each is in soluble form, which will rapidly leach out and be lost if exposed in rainy weather.

Well kept, dry hardwood ashes carry about 5 per cent of potash and pine wood ashes 3 to 3½ per cent. Ashes also contain about 30 per cent of lime. Lime is not to be generally recommended for bright tobacco, but the moderate quantity contained in the ashes used as a source of potash would probably not do much if any harm and might under some circumstances be beneficial, as explained in the section on the use

of lime on page 19. It should be remembered, however, that ashes are not suitable for use in a mixed fertilizer, because if such a mixture stands any considerable length of time the lime may react, with the ammonia compounds of the fertilizer forming gaseous compounds which will escape and be lost. The best way would be to apply the ashes along the row separate from the rest of the fertilizer.

In the New Belt section tobacco stalks are not generally available for use as a fertilizer, because under the priming system they are left standing in the field. In the Old Belt where cutting the entire plant is the custom stalks in considerable quantities are available. If kept from the weather, stalks from the flue-cured district contain generally around 2 per cent of ammonia and from 1¾ to 2½ per cent of potash. In the absence of an actual analysis of a given sample, the stalks might be estimated to contain in round numbers about 2 per cent ammonia and 2 per cent potash.

Stalks at the rate of 600 pounds per acre will contain as much ammonia and as much potash as 400 pounds of ordinary 3-8-3 fertilizer. The stalks also contain around 0.6 of 1 per cent of phosphoric acid. If, therefore, 160 pounds of 16 per cent acid phosphate per acre be used in addition to the 600 pounds of stalks, the resulting plant-food value of the stalks and acid phosphate, as judged by analyses, will be the same as 400 pounds of 3-8-3 fertilizer.

The stalks may be ground or not and distributed in the row. Unless ground very fine, however, it will be difficult to mix them uniformly with the acid phosphate, because there is such a great difference in the consistency of the two materials, and it would doubtless be best to apply the stalks separately.

Some growers have expressed the opinion that stalks injure the quality of tobacco, but so far as there is any foundation for this, it is in all probability due to the fact that they have been used like manure, spreading them broadcast in much too large and unknown quantities, so that the tobacco was overfertilized, particularly in respect to ammonia.

In the New Belt section, with the combination of lighter and weaker soils and early harvesting in warm weather, a materially richer fertilizer could undoubtedly be used to advantage in most cases, and for that section a mixture may be recommended for average conditions composed about as follows:

Formula No. 1.

Dried blood analyzing 16 per cent ammonia	250 lbs.
Acid phosphate analyzing 16 per cent phosphoric acid	500 lbs.
Sulphate of potash analyzing 50 per cent potash (K_2O)	150 lbs.
Total	900 lbs.

This mixture of 900 pounds for an acre of land would be equivalent in plant-food value to 1,000 pounds per acre of a fertilizer analyzing 8 per cent of phosphoric acid, 4 per cent of ammonia, and 7½ per cent

of potash. On the very lightest soils of the New Belt section, for reasons already mentioned, better results might be obtained by reducing the acid phosphate, say, to 400 pounds, or by increasing the blood (ammonia) to 300 pounds or more, thus narrowing the ratio between the ammonia and the phosphoric acid to 5 or 5½ to 8 instead of 4 to 8, as shown in the formula given.

Fertilizers for tobacco are generally applied in the row, and when used in the ordinary quantities better immediate effects are no doubt realized. When considerable fertilizer is used in the row, even in the quantities mentioned above, it should be thoroughly incorporated with the soil by running a double-shovel plow with narrow teeth along the row before it is bedded. When large quantities of fertilizer are used it might be best to apply at least half broadcast.

In connection with the use of fertilizers it is assumed that the humus supply has been given due consideration, thus insuring a good physical condition and moisture-holding capacity. A tight, drought stricken, or badly drained soil cannot be expected to become very productive just by increasing the supply of plant-food in the form of commercial fertilizers.

In the above discussion no special mention has been made of the relative value of the different sources from which the plant-food material may be derived and this has purposely been omitted for the sake of brevity. It should be stated, however, that the materials mentioned may be regarded as standard, in the light of our present knowledge, and as good as anything now on the market.

As a source of potash, however, the sulphate should generally be given the prefence in a tobacco fertilizer. The other materials most likely to be used as a substitute are muriate of potash and kainit. Both of these materials contain large quantities of chlorin, which has a tendency to make tobacco burn poorly. Complaints have frequently been made as to the poor burning quality of flue-cured tobacco from the New Belt section, and it would be unwise to use anything in the fertilizer which would tend to strengthen the basis for this criticism.

BARN MANURE FOR FLUE-CURED TOBACCO

While commercial fertilizers are, and of necessity must remain, the chief reliance of the tobacco grower, barn-lot manure is used to some extent on bright tobacco, although there are opponents as well as advocates of its suitability for this crop. In so far as its use may be considered objectionable, the objection has the same basis as that of other organic materials overrich in ammonia, namely, the tendency to make the tobacco coarser and darker. The lighter and poorer the land in respect to other ammoniates, the more likely is the manure to be found desirable and advantageous. The way in which the manure is used is also an important factor in determining its effect on the quality of the crop. If well rotted, and applied some months before the tobacco is planted, it can generally be used in moderate quantities with decided benefit,

except, as already indicated, on land already rich in ammonia. Where possible, it should be applied in the fall before planting the tobacco, or certainly not later than the first of March. When used at the rate of 2 or 3 tons to the acre it can be applied in the row. When used in larger quantities (5 or 6 tons to the acre is about as heavy as it is generally advisable to use manure for bright tobacco as a direct application), it should be broadcast over the land and either harrowed or plowed in. Only fine, well rotted manure should be used in the row, and it should be applied as much as two months before planting, if possible. In using manure in this way the rows may be laid off in February or early in March and the manure put out and covered with the turning plow. Just before planting time these rows may be reopened with a single-shovel plow, the additional fertilizer applied, and the land rebedded in preparation for setting the tobacco.

Where tobacco succeeds herds grass in the rotation, an excellent method is to apply the manure to the grass during the winter, preceding the last season the field is to stand in grass. This would greatly help the hay crop and give the manure time to become thoroughly decomposed and incorporated with the soil.

THE USE OF LIME ON FLUE-CURED TOBACCO SOILS

Most flue-cured tobacco soils contain sufficient lime to fill direct plant-food requirements, but not enough generally to keep them from becoming rather acid. Their general crop-producing power through enhanced bacterial efficiency usually would be improved if they were occasionally limed. The grass, especially, would yield much better if lime were occasionally used. The direct effect of lime on the tobacco, however, may be somewhat injurious to the quality. By hastening the decay of the vegetable matter in the soil it increases the ammonia supply, and on soils already tending to be overrich the lime will tend still further to make the tobacco dark and coarse, the same as if increased supply of ammonia were rendered available in any other way.

On some very poor soils, however, lime might result in both a larger yield and better quality because of the increased food supply rendered available.

It is somewhat a matter of controversy, also, whether lime does not tend to injure the burning quality of tobacco. When lime is used in the tobacco rotation it seems wisest, therefore, to use it immediately after the tobacco comes off and before the wheat or oats are seeded. It would thus tend to help the immediately succeeding crops, particularly the grass, and would be largely out of the way, so far as its direct effect is concerned, by the time the field is again planted to tobacco. On tobacco lots lime should not be used ordinarily oftener than about once in four years and at a rate not to exceed one ton of ground limestone per acre.

VARIETIES OF FLUE-CURED TOBACCO

A great array of so-called tobacco varieties might be listed, but many of them would represent but little, if any, real variation in type. There is, however, one broad differentiation among the many so-called varieties, based on shape and size of leaf which can readily be observed. Thus we have the broad-leafed types, represented by such standard sorts as Warne and Yellow Pryor, White Stem Oronoco, Big Oronoco, Adcock, Willow Leaf, Gooch, Tilley, and Hester, and the narrow-leaf sorts, as Narrow Leaf (little) Oronoco and Flanagan.

Throughout the New Belt and on the lighter soils of the Old Belt section the broad-leaf types are generally preferred, as they are better adapted to the production of smokers, cutters, and wrappers. On the stronger soils of the western part of the Old Belt section, particularly westward from Rockingham County, N. C., and Henry County, Va., the narrow-leaf sorts are general favorites. These narrow-leaf varieties will make good rich fillers on suitable land, and by somewhat closer planting on improved land a larger yield per acre can be grown without the individual leaves becoming overgrown and coarse. Flanagan and some of its subtypes, particularly the improved Flanagan, are rather large-leaf types, about midway between the narrow-leaf and the broad-leaf sorts, and are well adapted to quite rich land.

The variety known as the Short Stalk Flanagan closely resembles the Narrow Oronoco. The Flanagan types are perhaps the most vigorous growers and heaviest yielders of any of the flue-cured varieties, but they are a trifle later in maturing than the others.

On the fine bright soils the broader leaf types are generally popular, the Warne, the standard wrapper type, being perhaps the most popular of any. The White Stem Oronoco, Willow Leaf, and Gooch are favorites in certain parts of the New Belt section. The Adcock is a great favorite in the noted wrapper-producing section in the southern part of Granville County, N. C. The Adkin is also a popular broad-leaf sort in certain sections of the Old Belt and has the merit of being some days earlier in maturing than most of the other standard sorts, but this earliness is probably somewhat at the sacrifice of yield.

The distance between the leaves on the stalk is somewhat greater on these broad-leaf types than on the narrow-leaf sorts, the spacing being particularly wide in the case of the Adcock. It should be noticed that any of these varieties will have the leaves more closely or wider spaced according to the nature of the soil, especially in respect to moisture conditions. With an abundance of moisture the spaces between the leaves will be wider, and under droughty conditions the leaves will be crowded much more closely together. This is a general principle in respect to all vegetation.

SELECTION AND CARE OF SEED PLANTS

In selecting seed plants close attention should be given to all the points that go to make up the ideal plant according to the standard

which the grower should have clearly in mind. The largest plants in the richest part of the field are not necessarily the best for seed purposes.

FIG. 2. Seed head of tobacco covered with a paper bag to prevent mixing.

Pure strains of seed can be saved with certainty only by covering the seed head during the blossoming period so as to prevent mixing or cross-

ing with inferior plants or suckers by the passing of insects from flower to flower on different plants. For this purpose an ordinary light-weight but strong paper bag of about the 12-pound size, such as can be obtained at any grocery store, is most practical. A day or two before the first flowers open the bag should be tied about the head (Fig. 2) which first has been trimmed to a "crow-foot." The bag should be loosened and raised up every few days as the seed head grows and the flower débris shaken out.

After all the flowers of the "crow-foot" are open and the seed pods begin to swell, the bag may be removed if desired, but it will be necessary to keep all other flower branches and buds constantly picked off.

In harvesting, only the fully matured and ripe pods should be saved. Such as are underripe should be picked off and discarded. After they have been shelled out, the lighter, imperfect seed should be got rid of by some simple winnowing device, for the same reason that wheat or other seed are cleaned of inferior grain before sowing. A satisfactory separation of the seed can be made also by settling them in a glass of water. After half or two-thirds of the seed have sunk to the bottom, at the expiration probably of two or three hours, the floating seed may be skimmed off and the heavy seed that have settled can be dried on blotting paper.

PREPARATION AND CARE OF THE SEED-BED

It is the almost universal custom throughout the entire flue-cured district to prepare the seed-bed on freshly cleared land, either in the woods or in some other suitable location. The reason for this is that there is an abundance of humus in such land. It is not compacted and baked by heavy rains and the sun, and the plants grow faster on fresh land than on old land.

The particular spot of land chosen should be loamy and mellow, and naturally moist, but having good drainage and free from standing water at all times. It is desirable usually to locate the bed near a stream of water. At such places the land is apt to be naturally moist, and in the event of extreme drought the bed can be more readily watered artificially.

An exposure to the south or east will give the earliest plants, although it is best to have at least two beds, one a little later than the other. The spot chosen should also be as free from weeds or grass as possible and generally, as further insurance against a weedy bed and fungous disease and to kill soil insects as well, the bed should be burned during the winter before it is seeded. If plenty of good dry brush is available (pine brush is best), the bed can be most easily and cheaply burned with this material. About eight good loads of well compacted brush will usually be required for a bed of 100 square yards. Before the brush is piled on the bed, the leaves or other litter should be raked from it, as they hold moisture and would tend to prevent the heat from penetrating the soil to sufficient depth. If brush in sufficient quantity is not avail-

able, or it is desired to burn the land very thoroughly, a combination of wood and brush may be used. Burning in this way will require about 3 to 5 cords of wood for 100 square yards. Long poles or skids are laid along the ground at intervals of about 4 feet. Across the ends of these skids on the upper side of the bed brush and wood is piled about 4 feet wide and 3 feet high. This pile is set on fire in several places. With considerable attention it will generally burn down sufficiently in about half an hour. The embers are then pulled down with hoe or hooks with long handles to the adjacent strip 4 or 5 feet just below. The fires are renewed by piling on more wood and brush and allowed to burn down for another half-hour, or until the soil beneath seems well heated and dried out to a depth of about 3 inches. The process is repeated until the whole bed is gone over. The scarcity of wood in a great many sections of both the New and Old Belts have made the burning of seed-beds very expensive, and in many cases the land is not burned at all, but new places in the woods are located on land well covered with leaves and trash where weed seeds are not likely to be present. In some instances seed-beds have been placed in broom-sedge fields, without burning, and with a liberal application of fertilizers and manure splendid results have been obtained. In preparing a bed without burning care must be exercised to select a place as free as possible from weed or grass seeds. Usually the plants on an unburned bed are a little slow in growing off, but when the weather begins to warm up they will get large enough to transplant as quickly as those on a burned bed.

A spell of dry weather when the ground is free from frost should be chosen for burning. If the soil is wet, it will take much more heat to burn with the same efficiency because of the increased amount of water to be evaporated, and in some cases the physical condition of the soil might be injured if burned when too wet. The bed may be burned at any suitable time during January or February or even as late as the middle of March in the western part of the Old Belt section. The burning of the soil puts it into good tilth, and generally it can be worked up and sowed to best advantage at that time. A disadvantage is the danger of washing the seeds away by heavy rains, or they may sprout prematurely during protracted warm spells in the winter months and be killed by later cold snaps. This, however, rarely happens, and generally the seed will not come up till about the last of February or first of March in the New Belt section or about the middle of March in the western part of the Old Belt section. In fitting the bed after burning, or if fitted without burning, as is sometimes done on weed-free land, a single-shovel coulter plow is of great service. After raking off the embers the bed should be gone over both ways with a single-shovel plow and then several times with a drag harrow. This will minimize the amount of hand work required in fitting to a fine surface tilth. Fertilize liberally by raking in about 1 pound per square yard of some good fertilizer such as 3-8-3 or its equivalent. If the bed has been burned, the ashes will give enough potash, but phosphoric acid and ammonia will be required.

Blood or cotton-seed meal are good forms in which to apply ammonia at the time of seeding, but about the time the plants should come up a top-dressing of nitrate of soda, at the rate of 5 pounds per 100 square yards, will start the plants to growing vigorously. Unless absolutely necessary, nitrate of soda should not be applied to a bed after the plants have attained much size, because it will force them into a late tender growth at transplanting time, and they will be less likely to live.

A moderately heaping tablespoonful of good seed is enough to sow 100 square yards of bed. If too much is used the plants will be spindling from being too thick, and they will not thrive when transplanted. This quantity of seed should be mixed with about 1 peck of good sowing material, such as fine dry fertilizer. In sowing, the bed should be gone over both ways in order to insure an even distribution. One of the best methods of covering the seed is by tramping with the feet. This compacts the soil and presses the seed into it. If the bed is sufficiently smooth a hand roller might be used, but it would not usually be practicable for use on an ordinary bed in the woods.

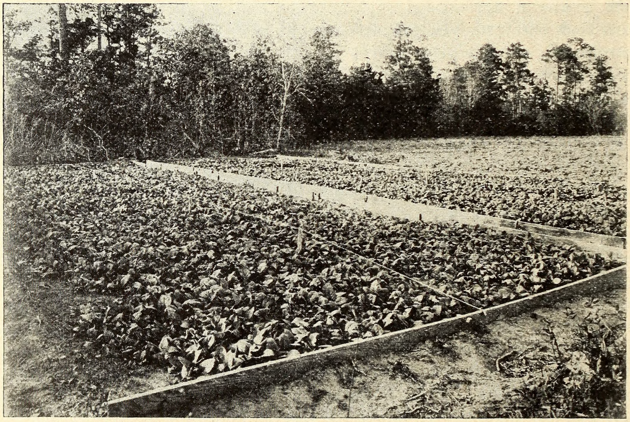

FIG. 3. Bed of tobacco plants, with the cloth removed, ready for transplanting.

After danger of snow is over, not later than about ten days before it is time for the seed to come up, the bed should be boxed in tightly with poles or plank about 6 inches high and covered with plant-bed cloth. The cloth will retain the warmth and make the plants earlier, and if tight all around and free from holes will keep out flies and other insect enemies. The cloth is kept from sagging to the ground by stretching wire on poles across the bed at intervals of about five steps, or by placing wickets made from green switches here and there over the bed.

About the time the plants begin to come up it is a good plan to sow an additional half tablespoonful of seed over the bed on top of the cloth. The rains will carry the seed through the cloth into the soil, and this extra seeding will make a good late drawing of plants which may prove useful, and in any case will not interfere with the first sowing.

If the beds get weedy they should be picked over by hand, preferably during a spell of wet weather. A few days before transplanting the cloth should be removed to harden the plants, or they may be removed earlier if the plants are becoming overgrown.

Always to have an abundance of plants when needed is a fundamental factor for success in tobacco growing. Without plants the whole year's work is a failure. A good bed may supply as many as 40,000 to 50,000 plants from 100 square yards in two or three drawings, but it is not safe to count on more than 10,000 to 15,000 plants from each 100 square yards sowed. A plant-bed with the cloth removed and plants ready for transplanting is shown in Fig. 3.

EARLY AND LATE PLANTING COMPARED

The transplanting season in the New Belt section begins about the middle of April in eastern North Carolina and continues until as late as the middle of June in the western part of the Old Belt, although even in this latter section the main plantings are made from about the middle to the last of May. In the New Belt the bulk of the crop is generally set by May 1. The tobacco which reaches maturity and is harvested while the weather is yet warm, say, from the middle of August to the middle of September in the western part of the Old Belt section, generally will be decidedly better in quality, particularly in respect to color, than the later cuttings. In the New Belt and the eastern part of the Old Belt the harvest season, running through July and August, naturally comes in warm weather, and this is a distinct advantage, but even there the earlier curings are likely to be best in quality. Fairly early planting is to be preferred, therefore, even in that section, and the plants live better if transplanted before the weather becomes too hot and dry; but in the western part of the Old Belt the grower should make a strenuous effort to have an early crop by planting early and by choosing land on which the plant will grow off quickly.

PREPARATION OF THE SOIL FOR TRANSPLANTING

As already indicated, the best system of tobacco farming, particularly in the Old Belt, will provide for the fall or winter plowing of the tobacco land. The winter freezing will mellow the soil and the winter and spring rains will be better held for the use of the growing crop during the summer. Little faith should be placed in the oft-heard assertion that shallow plowing (3 or 4 inches) is best for tobacco, although in the Old Belt it probably would be unwise to turn up any considerable quantity of a stiff clay; but unless the field can be plowed as much as 6 inches deep without so doing it is probably not well suited to bright tobacco.

If the field has been fall or winter plowed no further preparation will be necessary until in the spring it is time to fit the land for transplanting.

The disc harrow is the best implement for working the soil into a good tilth, if followed by a drag harrow just before laying off the rows.

DISTANCE OF PLANTING

The space allowed each plant in the field, that is, the distance of planting, is a matter of considerable importance in determining the quality and to some extent the yield of tobacco produced. Careful attention should be given the matter of proper spacing when setting out the crop, and a strenuous effort should be made to secure a good, even stand over the whole field as promptly as possible. The real importance of this matter will be made clear by observing the effects of a broken stand of plants on an improved field, just before the harvest. Where the stand is regular, the tobacco will probably be smooth and fine and ripen nicely. But where some of the plants are missing the surrounding plants will be overgrown and coarse, and will neither ripen, yellow, nor cure well. Because of the increased feeding space, without competition from other plants, they are overfed and rendered overgrown and coarse and of greatly diminished value.

In the flue-cured district the customary distances of planting give about 4,000 to 5,000 plants to the acre. In the New Belt it is more usual to space the rows about 4 feet apart, with the plants from 2 to 2½ feet apart in the rows; and in the Old Belt, particularly in the western part, the more common distance between the rows is 3½ feet, with the plants from 2½ to 3 feet apart in the rows. The reason for the wider spacing of the rows in the New Belt doubtless is largely the cause of the greater convenience in getting through the wider rows with the mule and truck used at harvest time for hauling out the leaves, and also because the tobacco grows taller and would thus tend to more self-shading in the narrow row. In some sections of the New Belt it is customary to make every eighth row 6 inches wider than the others, and at harvest time the mule draws the truck or slide, into which the leaves are put, through this wider space with less danger of breaking the tobacco standing in the rows on either side.

As the soil becomes richer by better farming methods, much of the tendency for the tobacco to grow coarse and dark can be overcome by thicker planting combined with somewhat higher topping. In some cases 3½ feet between the rows and 2 feet between the plants in the row would not be too close for the best results in yield and quality.

LAYING OFF THE ROWS AND TRANSPLANTING

For laying off the rows the bull-tongue, single-shovel plow is a good implement. After distributing such fertilizer as is to be used in the row, it should be incorporated with the soil by going along the row

with a double- or single-shovel plow or other suitable implement, after which the rows are bedded by turning two furrows together with a one-horse plow. In a few sections a four-furrow bed is made, on the theory that the wide bed holds the moisture better and gives the plant a better start. In most sections, however, the consensus of opinion seems to be that the two-furrow bed is just as satisfactory. In the light soils of the New Belt the bed is put into final shape for planting by dragging down and slightly packing the top of the ridge. A cotton planter drawn along the row is frequently used for the purpose, the plow in front serving to knock off and flatten the ridge while the roller behind compacts the soil. A plank or log drawn by a mule and wide enough to cover two or more rows at a time is also a satisfactory device. Figure 4 shows an ingenious implement for this purpose devised and used by Mr. B. F. Williamson, a noted grower in Darlington County, South Carolina.

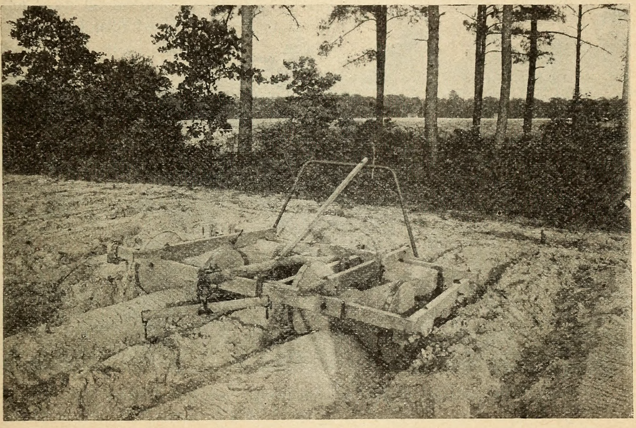

Fig. 4. An ingenious form of ridge leveler for compacting and leveling the beds or lists upon which tobacco plants are to be transplanted.

This device, by means of the spool-shaped rollers on the front, rounds off the bed so that water cannot form pools and drown the plants, and it flattens and compacts the bed at the same time.

On the rougher soil of the Old Belt section it is more customary to go over the field with a hoe, cutting through the bed and making a pat at each spot where the plant is to be set. The objects of the bed are to get a body of good soft soil in which to set the plant and to provide drainage that surface water during heavy rains may flow away from the plant and not stand around it, and either cover it with silt or drown it outright. But, in obtaining these objects, the less the elevation of the plant the better.

A splendid method of preparing the tobacco land in the Old Belt is to drag off the beds with an acme harrow or a spike-tooth harrow; this knocks down the bed somewhat, and at the same time pulverizes the topsoil, also helps to kill some of the grass seed that may have begun to germinate.

When transplanting, so far as possible use only good, strong plants of uniform size. The plant should be kept straight and the roots well mulched and protected from the drying wind and sun in order to retain their vitality as much as possible, which will help materially in insuring a good start in growing. In the flue-cured districts the greater portion of the crop is transplanted by hand in a natural season, using a

FIG. 5. The two-horse machine transplanter at work near Kinston, N. C.

peg for making holes and pressing the earth to the roots. But more or less setting with water in times of drought is resorted to almost every year in some sections. For this purpose a special hand-planter is often used. This is an effective and inexpensive implement. It has the merit of putting the water immediately around the roots where needed, and it is thought that the plants grow better than when set and hand-watered with dippers.

The two-horse machine setter is in use to a limited extent in some neighborhoods, but, of course, is adapted only to smooth fields and soft land. A view of one of these machine setters at work in Lenoir County is shown in Fig. 5. The expense of machine setting is about the same as for hand setting, but there is the advantage of being able to go ahead with the setting when the plants are ready independently of the weather.

The water is put at the roots and the plants live as well or better than hand-set plants.

In three to five days after the field is set it should be gone over again and carefully replanted with the best plants available. A strong effort should be made to secure a perfect stand as soon as possible. This is a very important point in securing the best results from tobacco.

CULTIVATION OF THE GROWING CROP

In order to encourage a quick start in growing, a good horse cultivation and careful hand hoeing should be given the newly set tobacco as soon as it becomes established, generally in about a week or ten days. A little fresh earth should be drawn about each plant, but care should be taken not to loosen the newly established roots. A second hand hoeing may be needed about two weeks later; but in any case the young tobacco should be horse cultivated every week or ten days, according to conditions, until about topping time. After topping cultivation should be discontinued, as the tobacco will ripen better if cultivation is not continued too late. From four to six horse cultivations can generally be given to advantage, although many growers usually give but three. If the soil is at all hard, the first one or two cultivations should be deep to thoroughly loosen up the soil and render it mellow. A double-shovel plow with narrow teeth is useful for this purpose. Later on, as the roots begin to spread through the row, only shallow cultivation should be practiced. For these later cultivations, especially, the ordinary five-toothed cultivator, fitted with an 18-inch or 20-inch sweep on the rear tooth, is a very satisfactory implement. The sweep attachment fills the furrows made by the teeth and works the soil toward the plant. Such a slight raising of the soil along the row is undoubtedly desirable; but it is open to question whether the excessive bedding of the row with the turning plow, as commonly practiced in "laying by" the crop, as it is called, at the last cultivation is desirable, except perhaps in very wet years or on soil characterized as wet or "spouty."

DISEASES AND INSECT ENEMIES

Specking, or "diseasing" as it is generally called, is the most common disease injury to which tobacco in the flue-cured district is subject. It is believed to be a fungous disease, disseminated by spores, perhaps of several species. The trouble is favored by a moist atmosphere and by sappy tobacco. The only practical method of reducing the injury from this trouble, so far as known to the writers, is by using potash more liberally in the fertilizer, which seems to increase the resistance of the plant to the disease.

Root-knot, caused by nematodes or eel worms of semi-microscopic size, also does great damage, particularly on some of the lighter soils of the New Belt section of the State. Nematodes also attack a long list of

plants other than tobacco, and the only way to free a field from the pest is by absolutely clean-fallow cultivation for a year or two or by growing only immune crops for two or three years so as to starve them out.[1]

The Granville wilt, first observed in the eighties of the past century, is a bacterial disease communicated through the soil. In the flue-cured district the infested area is largely confined to one soil type in the southern part of Granville County. This soil naturally produces a very fine type of wrapper tobacco. The disease is spreading quite rapidly locally and now occupies a considerable area in that section, embracing one of the very best tobacco areas which we have.

It was formerly thought there was no practical means of controlling the wilt after the soil was once infested, but recent investigation by the North Carolina Experiment Station and the Tobacco office of the Bureau of Plant Industry have demonstrated that it can be controlled by the use of the proper system of crop rotation, and by preventing weeds, many of which were hosts for the wilt bacteria, from growing on the land. However, it is difficult to prevent the wilt from gradually spreading from one field to another, and every precaution should be used to prevent its spreading. While it is largely confined to one soil type, yet it has been observed in different sections of the State during the past two or three years.[2]

The Mosaic Disease, frequently spoken of as calico or "mottling" and in this State commonly spoken of as "Walloon," probably is the most widespread of all the tobacco disease. Until recently it has been quite generally supposed to be simply a manifestation of malnutrition, caused by unfavorable growing conditions. It has long been known to be infectious, however. It can be spread, for example, by rubbing the leaves of a diseased plant and then likewise rubbing the leaves of healthy plants. Recent tests by H. A. Allard of the Bureau of Plant Industry go to show that the disease is a specific infection, and in the absence of such infection cannot arise from impaired nutrition. It has been discovered that certain aphide, or plant lice, are largely responsible for the dissemination of the disease. Other names, such as frenching, walloon, etc., are applied to a group of diseases resembling true mosaic, more or less. Such diseases as so-called "sore shin" and "rotten stalk" are sporadic and occasional in appearance, and are thought to be due primarily to some mechanical injury which may admit disease germs that attack the tissues locally.

Tobacco at various stages of its growth is subject to the attacks of a number of insect enemies, for a list of which, with recommendations for controlling them, the reader is referred to Farmer's Bulletin 120 and Circulars 120 and 173 of the Bureau of Entomology of the U. S. De-

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[1]For a full discussion of nematodes and methods of eradication, see "Root-Knot and its Control," U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin No. 217, 1911.

[2]For a full discussion of the Granville wilt, and methods of controlling same, see Bulletin No. ...., U. S. Department of Agriculture and North Carolina Experiment Station.

partment of Agriculture. Also special bulletin on "Insect Enemies of Tobacco," by N. C. Department of Agriculture, supplement to October, 1909, Bulletin.

TOPPING AND SUCKERING

In about eight or nine weeks after transplanting in seasons of normal growth, the tobacco plants will begin to show signs of sending up a seed head, "buttoning out," as it is called. The topping season is now at hand. In topping the aim is to improve the quality of the leaves produced and to aid the different plants in maturing at the same time. Experience and judgment are necessary in this important operation. From 8 to 12 or more leaves, excluding undeveloped leaves, at the bottom are commonly left to mature on each plant. Primarily, the number of leaves that should be left depends upon the richness of the soil and the vigor of the plant. If the plant is topped too low the yield will be unnecessarily sacrificed and the remaining leaves will be coarse and overgrown. Sometimes in the Old Belt section some of the inferior bottom leaves are primed (broken off) and discarded at the time of topping the plant. In the New Belt, where harvesting by picking the leaves is general, it is customary to top somewhat higher than in the Old Belt, often to as many as 16 or 18 leaves.

The time required for a plant to mature depends somewhat on the number of leaves left on it. In order to bring as many plants as possible to a uniform state of ripeness at one time it is customary to let the bud come out somewhat higher and to top to more leaves at first and to one or two less each subsequent time the field is gone over.

Soon after the plants are topped suckers will begin to grow from the axils of the leaves. The first suckers will appear at the top of the plant and so on downward as the upper ones are broken off. Two full sets of suckers will usually grow on a plant, but it will be necessary to go over the field as many as five or six times at intervals of about one week in order to get them all. The whole object of topping will be defeated if these suckers are allowed to grow, and generally they should not be permitted to get more than 4 inches long before they are removed. Sometimes, however, when a period of wet weather comes just as the tobacco should be getting ripe, it may be of advantage to let the suckers remain temporarily, as their growth will tend to absorb the energies of the plant and prevent the leaves from taking on a second growth, which would make them coarse and dark.

HARVESTING

When the tobacco is to be harvested by cutting the entire plant, as is customary in the Old Belt, the general condition of the whole plant must be considered, allowing the top leaves to get as ripe as possible without too much loss at the bottom of the plant. Generally, a plant will be ripe in from 90 to 100 days after transplanting and in about 35

to 40 days after topping, but this is subject to great variation, dependent primarily upon seasonal conditions. When tobacco is to be harvested by priming, or picking the leaves off as they ripen, the harvest begins whenever the bottom leaves demand it, generally in about two or three weeks after topping or even before topping in some instances. The field subsequently will need to be gone over about once a week until all the leaves are removed, usually about four or five times in all. Fig. 1 shows a fine field of tobacco in the Old Belt section near Oxford, N. C., which is about ready for the harvest, and Fig. 6 gives a view of the field in the New Belt section near Greenville, N. C., which is in actual process of harvesting by the priming method. The more common form of low-

FIG. 6. Harvesting tobacco by the priming method. The form of truck shown, with a high body which passes over the tops of the standing plants without damage, is convenient for hauling out the leaves.

wheel truck for hauling out the leaves is shown in Fig. 7. To cure up sweet and with good color, particularly on the stiffer class of soils of the Old Belt sections, the tobacco must be ripe when harvested, but if overripe it will be lacking in toughness and luster.

The question of comparative merits of the priming method as compared with cutting the entire plant is somewhat complicated by local conditions and is a matter of considerable controversy. Theoretically the priming method, whereby each leaf is taken at approximately its stage of maximum development, should be best. The priming method requires somewhat more labor than the cutting method, and the New Belt section has this labor in better supply, owing to the surplus that can be shifted temporarily from the cotton fields. The lighter soils of the New Belt and the consequent greater tendency in many cases for the

bottom leaves to waste before the top leaves are ripe makes the priming method relatively more necessary than in the Old Belt, where the stiffer soils retard deterioration of the bottom leaves while the top leaves are ripening.

In seasons of normal growth, under the conditions existing in the Old Belt, when all the leaves of the plant mature at approximately the same time, quite likely the crop may be most economically and satisfactorily harvested by cutting the entire plant at one time. But when, as in 1912, a prolonged drought causes the bottom leaves to turn yellow and waste away while the top leaves are still green, there can be no question that it is much better to prime off leaves as they ripen, as was actually done by many growers. If priming had been universally followed in

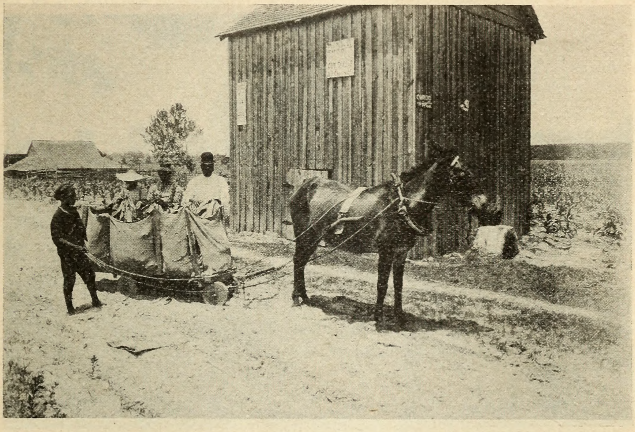

FIG. 7. Showing a common type of low-wheel truck in the New Belt Section, in which the tobacco leaves are placed as they are picked.

that year, undoubtedly it would have saved many thousands of dollars to tobacco growers of the Old Belt section. Recent experiments conducted at the Branch Experiment Station near Oxford, N. C., by the Tobacco Office of the Bureau of Plant Industry and the North Carolina Department of Agriculture show that the yield may be increased 20 per cent to 25 per cent by priming the leaves off as they mature in comparison with harvesting the plant by cutting. Also present market conditions demand bright tobacco, which can be more uniformly obtained by priming than cutting, consequently more money can be made by priming. For detailed information regarding these experiments write to North Carolina Department of Agriculture for bulletin on "Priming vs. Cutting Tobacco."

CURING AND HANDLING

The expert curer exhibits his skill from the very first as he begins to harvest the crop. He cuts or primes, having clearly in mind what he expects to accomplish in making the cure. For a uniform curing of good color a first requisite is that the barn be filled with plants or leaves of uniform ripeness and character.

The first step in curing is to yellow the leaf properly. This takes place while the plant is yet living but is slowly approaching death from starvation, since the food and moisture supply is cut off. To expose too long to the sun and air after cutting, even though actual sunburning does not result, greatly diminishes the vitality of the cells of the leaf and it will not yellow so well. The tobacco should, therefore, be housed

FIG. 8. Tobacco harvest in the New Belt Section. Stringing the primed leaves under the shade of a tree.

without excessive wilting or long exposure to the sun and wind. As soon as the leaf is dead or dry, further yellowing takes place only very slowly, and if there remains any considerable amount of moisture in the leaf a red or brown color will immediately begin to develop. In curing, one should keep well in mind the principle that it is necessary to preserve the life (cell activity) and at least some of the moisture while the leaf is yellowing, and so manage as to have the moisture exhausted by the time it is completely yellow, or, rather, a little before it is fully yellow, as the most satisfactory cures and clearest colors generally follow when the leaf is dried out with some green remaining in it. Tobacco yellows best, especially in the first stages, when the temperature of the barn ranges from about 80° to 100° F., but it will continue to yellow in the later stages up to 115° or 120°.

As the yellowing proceeds, it is well, towards the later stages, to increase the heat slowly toward these higher temperatures and to begin to dry a little on the yellowest leaves by admitting a little extra ventilation.

In order to obtain the best results in yellowing under varied conditions, it is best to have the barn very tight, so that in the earlier stages of yellowing the desired temperatures may be obtained without exhausting the moisture too rapidly. As the yellowing progresses, however, it is necessary that the moisture be gradually and later more rapidly removed; and to accomplish this to the best advantage it is highly desirable that the barn be so arranged as to be fully and freely ventilated, so that it may be possible to steadily remove the warm, moisture-laden air as it becomes saturated.

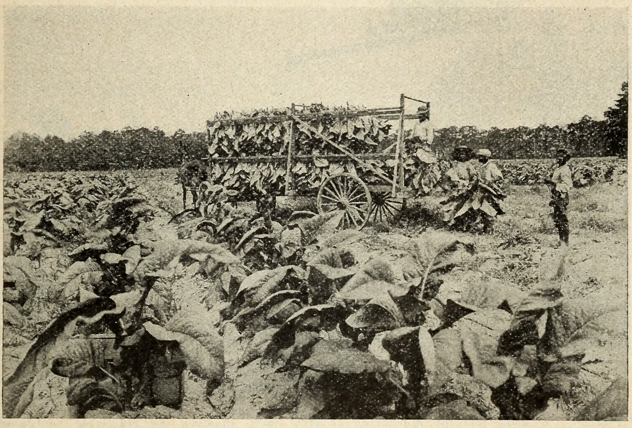

FIG. 9. Harvesting tobacco by the whole plant method, showing a good type of hauling frame which should be more generally used.

In drying out an ordinary 16-foot or 18-foot barn, holding, say, 500 sticks of cut tobacco, about 4,000 pounds of moisture (water) must be removed. The movement of the air through ventilation is the only means of getting rid of this large amount of moisture. Raising the temperature of the air increases its capacity to absorb the moisture and creates a draft, provided means are afforded in the construction of the barn for letting out the air rapidly at the top and for letting it in at the bottom. For the outlet at the top a short lever device at each end of the peak for raising the ridge-board by means of wires reaching to the ground, as shown in Fig. 10, is a handy and simple arrangement.

The slit left open when the ridge-board is raised should be about 5 inches wide. To admit air there is always the door, which can be par-

tially opened at will; but this method gives an excess of air immediately in front of and over the door. For an even distribution of the air in all parts of the barn, sewer pipes, about the 4-inch size, set in the walls at appropriate places, will make a good arrangement for the bottom ventilation.

The pipe should be set in the wall close to the ground, but just above it on the outside; they should dip just below the ground on the inside, the opening of the different pipes being, respectively, under and near the ends and at the middle of each length of flue, including the returns. Each air pipe should be fitted on the outside with a suitable wooden stopper to be closed or opened more or less as the conditions of curing require.

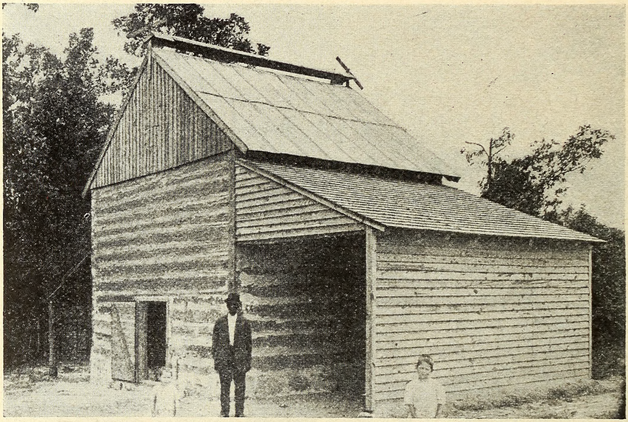

FIG. 10. A good type of flue-curing tobacco barn, showing the ridge-pole ventilator raised. The mouth of one of the bottom air inlets is seen just under the open door.

Generally it will be found best to begin to open these ventilators and raise the heat pretty soon after the fires have been started that the moisture may be sufficiently exhausted by the time the tobacco is yellow to prevent reddening or sponging. The draft should not be too strong, especially at first, but it should be sufficient to effectively remove the air before, or at least by the time it becomes saturated.[1]

In light-bodied tobacco, as grown on the lighter soil type, the yellowing process will generally take about 36 to 48 hours under average conditions; but if the tobacco is very heavy and dark, as frequently occurs on the filler soil types in the western part of the Old Belt section, it

[1]For full description of this barn write for Circular No. 18, "Tobacco Curing Barns," by E. G. Moss, N. C. Dept. of Agr.

may be necessary to consume three or four days in the yellowing process. This will be especially necessary if the soil on which the tobacco was grown was rich in ammoniates or if the tobacco was a little underripe when harvested. Under these circumstances there will be an abnormal quantity of reserve nitrogenous food material in the leaf, and it will be necessary to avoid applying much heat for several days or drying the leaf much, in order that these food materials may be consumed by the life processes of the plants, else the tobacco will be rank smelling, dark, and objectionable rather than sweet and agreeable. This explains why it is such a common practice with those who grow tobacco on the more clayey soils of the western part of the Old Belt to let the tobacco hang in the barn for a day or two before any fire is used at all and then to keep the temperature comparatively low so as to prolong the yellowing period, which in this case is really a ripening and sweetening period as well.

When the yellowing of the leaf is approximately completed, during the latter stages of which the temperature has been maintained at from 110° to 120° F., it is the custom to move up the temperature quite rapidly, say, at the approximate rate of 2½ degrees per hour to 130° or 135°, and to hold it at that point until the leaf itself is entirely dry throughout the barn, or at least on the bottom poles. It is a general rule of curing that it is not safe to exceed this temperature for any length of time before the leaf is dry, because at about this temperature, or a little above, the cells of the leaves are rapidly killed, and when killed they at once release the moisture they contain, which comes immediately to the surface and results at once, by oxidation, in a blackish discoloration known as scalding. Scalding may occur at a much lower temperature than this when the tobacco is full of sap, in the early stages of the cure. When the leaf is dry throughout the barn the ventilators may be partially or perhaps wholly closed, to save fuel, and the heat gradually moved up at the rate of about 5 degrees per hour to about 175° for the light bright types, at which point the heat is maintained until all the stems and stalks are completely killed and dried out and the cure finished.

Tobacco will tend to redden slightly at a temperature of 180° or above. In the filler districts in the western part of the Old Belt section the stems and stalks are more commonly killed out at about 200°; and sometimes for the last few hours as much as 225° or even more is maintained. These higher temperatures are thought to sweeten the leaf, and a reddish, rich-looking "face" is imparted, known as "scorching." These excessively high temperatures, however, although still extensively used, may make the leaf more or less brittle, which renders it objectionable for chewing purposes.

After the cure is finished the tobacco ordinarily should not be allowed to come in high order for any length of time, especially in warm weather, or reddening and perhaps worse damage from mold or decay

may result. On the other hand, to keep the tobacco for some time in moderate warmth and moisture may be an advantage in eliminating any remaining green color.[1]

In the portion of the New Belt adjoining South Carolina a large proportion of the tobacco is generally sold as soon as it is cured, without either assorting or tying the leaves into hands. Of course, the system of priming the leaves as they ripen makes for an approximate grading, since the leaves taken off at any one time are from approximately the same portions of the different plants, representing the bottom, middle, or top leaves, as the case may be. When sold in that way the tobacco is allowed to come in soft order as soon as possible (generally in a day or two) after the cure is finished. The leaves are removed from the string and packed into the wagon body as straight as possible, and the load is immediately taken to the warehouse and sold. In other sections, however, the tobacco is more generally first bulked in the packing house on the stick as it comes from the curing barn, either in the shingle bulk, as is more customary in the New Belt section, or in the square coop, as is more common in the Old Belt section; or it may be hung up in the packing house or curing barn, the sticks crowded closely together to keep the leaf from coming into high order, which would cause it to turn red. The tobacco is then graded and tied into hands at any time convenient to the grower, and sold as desired.

Except in cool, very dry weather, tobacco will generally come into order so that it can be removed from the curing barn on or about the second morning after the cure is finished. All the doors and ventilators should be opened at night to let in the moist air. The web of the leaf will generally become fairly soft the first night. The next day the barn should be tightly closed if the weather is dry, in order to retain the moisture. At night the barn should be again opened fully. The stems generally become softer during the second night, so that the tobacco can be removed and bulked or rehung in the storage or packing house without breaking.

In ordering tobacco for stripping and assorting, an ordering cellar is a great convenience. The cellar generally is dug under the packing house floor to a depth of 6 or 7 feet, and should be large enough to hold at least a curing of tobacco. The cellar is fitted with light framework on which to hang the sticks of tobacco. Care must be taken to locate the cellar where there is sufficient clay in the subsoil so the walls will stand firm, and it must be situated so that water will not rise or flow into it.

It should be banked around outside to keep out surface water, and it would be safest to put a drain pipe in the bottom to carry off seepage. At least one small window also should be provided.

Fig. 11 shows a good type of ordering house and stripping room, which can be cheaply constructed. This building can be either 14 by 28 feet

[1]For more detailed information in regard to the process of curing tobacco, see Farmers' Bulletin 523, U. S. Department of Agriculture, entitled "Tobacco Curing."

or 16 by 32 feet, built of logs with a partition about the middle of the building with a door in the center of the partition wall. One end of this building can be used for an ordering pit, or room, the north end for a stripping room, with a window in north end. The ordering room can be dug out 2 or 3 feet, and an open steam box placed across one end immediately in front of the door on the south end opening into the ordering room. This steam box can be used when the tobacco will not soften up fast enough under natural conditions, or, if desired, this room can be built without excavating and depend entirely upon the steam box for ordering the tobacco. This box should extend all the way across the room, so it can be fired from the outside. This ordering and stripping room should be conveniently located, not too far from the packing house.

FIG. 11. Good type of combination ordering house and stripping room.

Frequently a stripping room is built as a shed on one side of the packing house, into which the ordering room opens by a door and steps. The best light, free from glare for stripping, will be obtained if the windows are mostly on the north side of the stripping room.

In assorting tobacco as it is stripped from the stalk, which is a common practice in the Old Belt, about four fundamental grades will generally be obtained from a given plant. There will be the trashy lugs, clean lugs, leaf and tips, as they are taken from the bottom, and then on to the top of the plant. In the actual assortment of an entire curing a number of secondary grades will be made, sometimes as many as eight or ten in all, based upon differences in color, texture, and body. A great number of grades are recognized by the trade, as wrappers, cutters, export leaf, fillers, smokers, etc., and each of these is subdivided into a

number of grades, but, of course, only a few of them would appear in any single crop or curing. The better grades of lugs and leaf are tied into comparatively small hands of about 10 or 15 leaves each, but the poorer lug grades are generally tied into larger hands of 20 to 40 leaves each. The hands or bundles are tied with a leaf, which is folded for this purpose by turning both edges backward and inward so as to form a neat band. This is then deftly given a couple of turns tightly around and partially or completely covering the butts of the leaves forming the bundle, beginning with the tip of the tie-leaf. The butt end of the tie is tucked through the hand between the leaves so as to wedge and hold the tie-leaf in place.

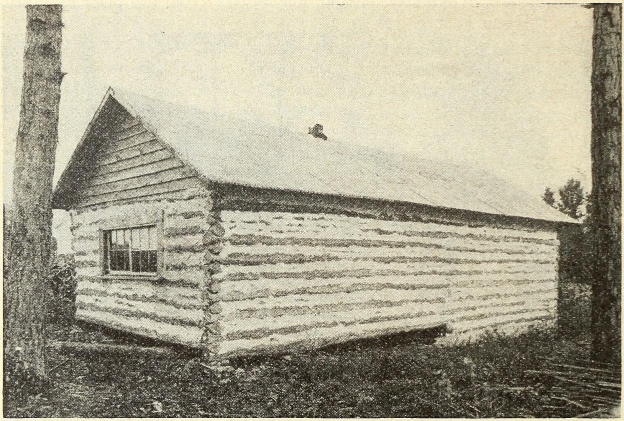

FIG. 12. A side view of house given in Fig. 11, showing the outside construction for ordering room in right end.

Before placing tobacco on the market, it should be brought into good but not too high order, and its appearance will be improved if it is bulked down either on or off the sticks for a day or two. In most sections of the flue-cured district the farmer can dispose of his tobacco either by direct sale on the warehouse floor or through the growers' pooling organization. If sold on the warehouse floor, care should be taken to avoid a glutted market, for at such time the prices are generally somewhat reduced because the buyers cannot handle and take care of it as fast as it comes in.

The entire cost of producing and marketing flue-cured tobacco is estimated at 6 to 10 cents a pound, according to conditions.

Several of the cuts in this bulletin were taken from Department Bulletin No. 16 of the U. S. Department of Agriculture, by E. H. Matthewson, also the general plan of discussion has been followed in this bulletin as in No. 16 of U. S. Department of Agriculture.

OCTOBER, 1916 TECHNICAL BULLETIN 11

NORTH CAROLINA

AGRICULTURAL EXPERIMENT STATION

CONDUCTED JOINTLY BY THE

STATE DEPARTMENT OF AGRICULTURE

AND THE

COLLEGE OF AGRICULTURE AND MECHANIC ARTS

RALEIGH AND WEST RALEIGH

SELF-STERILITY IN DEWBERRIES AND BLACKBERRIES

THE NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION

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4In coöperation with the U. S. Department of Agriculture, Office of Public Roads and Rural Engineering.

CONTENTS

SELF-STERILITY IN DEWBERRIES AND BLACKBERRIES

BY L. R. DETJEN.

INTRODUCTION

The phenomenon of sterility may be caused by any one of a number of various factors. It may be caused by external agencies, such as excessive heat, cold, moisture, and a host of other such conditions; but, more frequently, it can be traced to a deep-seated internal origin.

Sterility is encountered almost everywhere; it ramifies all branches of the plant and animal kingdoms. As an agent in the hands of organic evolution, sterility plays a rôle of prime importance, while to the breeder of improved forms it not infrequently becomes a menace and a stumbling block to further progress.

Sterility is a factor which is confined not only to the spheres of organic improvement and to evolution in general, but also to that of the production of fruit crops. In the latter field it becomes a factor of the utmost importance. In the planning of the older fruit plantations the factors of sterility were not recognized, and hence the innumerable financial failures, which, by a little knowledge of the comparative fertility of varieties, might well have been averted. Examples of this faulty planning of fruit plantations are very numerous, and only a few concrete examples will suffice to evince the real significance of the factors of sterility. Bartlett pear trees when set in large solid blocks have generally proven unprofitable to the grower. V. R. Gardner in his "Pollination of the Sweet Cherry," Oregon Experiment Station Bulletin, No. 116, points out the fact that among the more recent plantings of the sweet cherries, the fruit growers in Oregon have unconsciously selected varieties such as Napoleon, Bing, Lambert, and others, which are not only self-sterile, but also intersterile, as recent investigations have proven. In such cases even the selection of a list of varieties may not always constitute a remedy, and such practice when not carefully done may be no better than the planting of a whole block of a single self-sterile variety.

The large vineyards of Rotundifolia grapes in North Carolina give evidence of a lack of a sufficient number of pollinizers. These vineyards were planted upon the supposition that the different varieties of Muscadine grapes were self-fertile; but even so, in many instances provision was made for the cross-pollination of the different varieties. Later investigations regarding the self-sterility of rotundifolia grapes (N. C. Bulletin, No. 209) produced evidence that all of the cultivated varieties of these grapes are self-sterile, and also inter-sterile, and that

for successful fruit production the presence of male vines in large vineyards is absolutely essential.

Even the growers of small fruits are not immune from the harmful effects of sterility when certain varieties are planted in solid blocks. Fortunately for the commercial growers in the eastern States, the leading varieties of dewberries and blackberries are self-fertile and produce abundantly even when planted in large solid areas. However, there are many excellent varieties on the markets which are more or less influenced by the factor of sterility, and which, with judicious care in the selection of varieties with regard to pollination, can be made to yield profitable crops. In fact, there are a number of varieties which are likely to prove to be just as good as the chief commercial varieties of the present day, barring this one defect.

Object of the Experiment.—The prime object of the experiment under discussion was to investigate the question of sterility among varieties of dewberries and blackberries. This question resolves itself into the following three lines of investigation: first, to ascertain which varieties of dewberries and which varieties of blackberries are self-fertile and which are self-sterile; second, to discover, if possible, the cause or causes of this sterility; and, third, if possible, to suggest remedies.

STERILITY AMONG DEWBERRIES AND BLACKBERRIES.

Varieties Tested.—In order to provide sufficient material in the way of varieties to carry on this sterility test, the following varieties were secured and planted under ordinary field conditions:

Dewberries	*Hybrids*	*Blackberries*
Austin	Cox	Blowers
Chestnut	Ruth	Dallas
Grandee	Haupt	Early Cluster
Limekiln	Rathbun	Early Harvest
Lucretia	McDonald	Eldorado
Manatee	Wilson	Illinois
Munroe	Sorsby	Kenoyer
Rogers	Spalding	King
Elijah, No. 2		Mersereau
Premo		Minnewaski
San Jacinto		Snyder
White		

Method of Procedure.—The method used to test these varieties for self-sterility may be stated as follows: whole flower-clusters, and oftentimes several of them, were inclosed in bags so as to exclude all foreign pollen. Some of these bags were ordinary half-pound paper sacks, while others were made of cloth. The latter were made of Pacific lawn, which is a light, gauzy, but very fine-meshed fabric, and which successfully keeps out all foreign pollen.

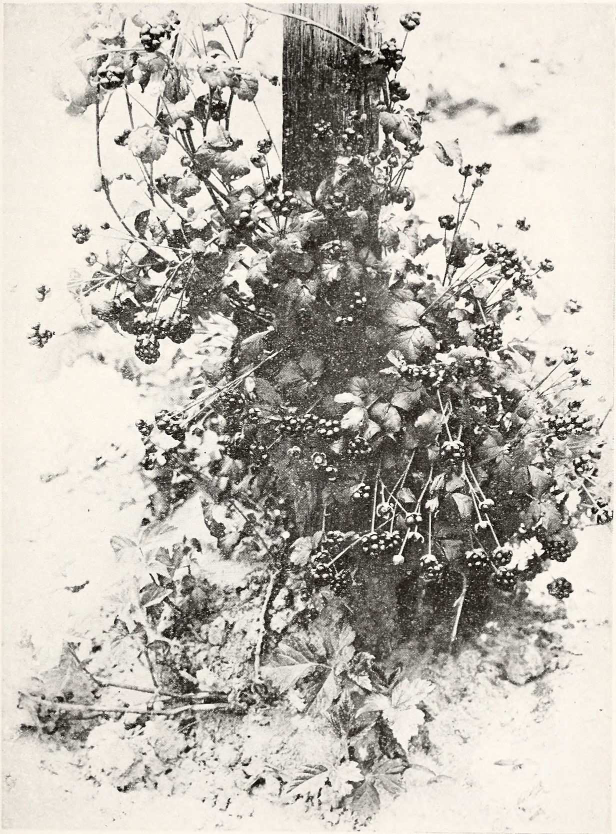

Fig. 1.—Premo, a self-sterile variety, produces a crop of nubbins when supplied with an insufficient amount of acceptable pollen.

The relative number of flowers inclosed in each bag depends entirely upon the species to which the respective varieties belong. Generally speaking, the flower clusters of *Rubus villosus* have relatively large numbers of flower buds, while those of *R. trivialis* usually possess from one to three.

By covering the flower clusters before any of the buds had opened or immediately after the careful removal of such as had opened, thus preventing all foreign pollen from gaining access to the flowers within, the potency of the pollen within the imprisoned flowers was tested. The flower clusters of each variety were covered during the forepart of their respective blooming periods, and to insure a length of time sufficient for fertilization to manifest itself the bags were not removed until it became evident to the most casual observer whether a fruit had or had not been formed. When the bags were removed a careful study of the inclosed fruits was made and the data recorded.

RESULTS AND DISCUSSION.

Dewberries.—The self-sterility work with the dewberries began with the planting of the varieties in the spring of 1908, and was finally completed in 1915, thus retaining the plants under observation for a sufficient number of years to warrant conclusions.

FIG. 2.—A fruiting branch of Manatee (dewberry.)

The results of the self-sterility test are set forth in the following table:

Table No. 1

DEWBERRIES.

Variety	Species	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Austin	Villosus	75	74	1	0
Chestnut	Trivialis	55	0	3	52
Cox	Hybrid	38	34	1	3
Ruth	Hybrid	27	26	1	0
Grandee	Trivialis	31	0	10	1
Limekiln	Trivialis	37	0	0	37
Lucretia	Villosus	30	28	2	0
Haupt	Hybrid	30	0	2	28
Manatee	Trivialis	71	0	20	51
Munroe	Trivialis	32	0	0	32
Premo	Villosus	56	0	0	56
Elijah, No. 2	Trivialis	23	0	0	23
Rogers	Trivialis	44	1	8	36
San Jacinto	Trivialis	58	0	1	57
White	Trivialis	59	0	1	58

By means of the above table we can readily group the dewberries and the hybrids (those grown as dewberries) into two well defined classes, namely, those that are self-fertile and those that generally are self-sterile.

The imperfect fruits listed with the self-fertile varieties will need no explanation, other than that untoward conditions frequently prevent the realization of an entire crop of perfect berries. But the imperfect berries listed with the otherwise self-sterile varieties need a few words of explanation. In the first place, the imperfect fruits, viewed from the point of commercial value, are negligible, for none of them were composed of more than eight druplets and most of them averaged less than four per berry. Furthermore, of those imperfect fruits produced by self-fertile varieties there were relatively many in each bag, while of those produced by the self-sterile varieties there were relatively few, not more than one fruit in the bag in most cases.

In the case of the Rogers variety, one bag produced one perfectly well formed and fully developed fruit. Besides this, eight bags with very small nubbins were also found. This well developed fruit undoubtedly was the result of the failure of the operator to remove a bloom which had already been fertilized and had dropped its petals. This fruit was produced in the year 1909, when twelve other bags produced only two imperfect fruits. This variety was again tested in 1910 and subsequently again in 1911. Of thirty-two bags recovered, no perfect fruits and only six very imperfect ones were discovered. We can thus safely disregard this one perfect fruit; but the imperfect ones of this

and of other generally self-sterile varieties must still be accounted for. These imperfect fruits are not the result of errors in bagging, nor are they the result of defective bags, for examination disclosed no perforations through which insects might have gained access to the flowers within.

These fruits, then, are the result either of self-fertilization, parthenogenesis, or of parthenocarpy.

In order to determine the real cause of the development of the imperfect fruits, three varieties, which in the self-sterility test showed the greatest development of fruits, were selected in the spring of 1915. Of the variety Manatee, thirty-four flower buds were carefully emasculated, and immediately covered with a bag so as to prevent the access of any foreign pollen. Of Rogers and Grandee, thirty buds each were selected, emasculated and carefully covered.

The prevention of self-pollination of flowers determines whether fruit production is the result of a sexual union or whether it is the result of parthenogenesis or of parthenocarpy. As a check on this work, fourteen flower buds of White and ten each of Rogers and Munroe were covered when the buds showed their pink unexpanded petals. These buds not only were not emasculated, but also when the flowers opened were carefully hand pollinated with pollen of the same variety. To offset any injury that might result from the process of emasculation, five buds of these same varieties, White, Rogers, and Munroe, were carefully emasculated and later cross-pollinated with the following varieties: White with Rogers, Rogers with White, and Munroe with Chestnut.

The results of the experiment were as follows:

Table No. 2

Manatee	34 buds, emasculated and bagged	No fruits set.
Rogers	30 buds, emasculated and bagged	No fruits set.
Grandee	30 buds, emasculated and bagged	No fruits set.
White	14 buds, not emasculated and pollinated	6 nubbins, 8 no fruits
Rogers	10 buds, not emasculated and pollinated	6 nubbins, 4 no fruits
Munroe	10 buds, not emasculated and pollinated	1 nubbin, 9 no fruits.
White	4 buds, emasculated and crossed	4 good fruits.
Rogers	3 buds, emasculated and crossed	No fruits.
Munroe	3 buds, emasculated and crossed	3 good fruits.

From the above table we note that not one of the flower buds that were emasculated and not pollinated showed any evidence of fruit formation. This fact becomes interesting in that it at once eliminates the two points under consideration, viz., parthenogenesis and parthenocarpy. Hence we are led to believe that the small nubbins of berries that we found in the bags to which no foreign pollen has been admitted are the result of a sexual union of elements from the same flower. In short, some few ovules in these otherwise self-sterile varieties of dewberries will

under certain conditions accept pollen from the same flower or from flowers of the same variety.

Of the flowers that were allowed pollen from the same flower and flowers of the same variety we find that, in the case of White, out of fourteen flowers inclosed, six produced fruit composed of a few druplets, and eight remained absolutely unaffected. The number of druplets that were produced by the flowers varied from one to five. Of the ten flowers of Rogers, six developed a few druplets and four developed none; while of the ten flowers of Munroe, only one flower developed a few druplets and nine absolutely refused the pollen.

That the injury done to flowers in the emasculation process, if carefully done, is negligible and does not affect the fruit formation is seen in the last part of the table where fruit buds of White were emasculated and crossed with pollen from the variety Rogers. Each of the four flowers that were emasculated and then cross-pollinated set and developed a normal good-sized berry. The three buds of Munroe that were treated in similar manner and then cross-pollinated with pollen from the variety of Chestnut also developed berries, normal in every respect. The three buds of Rogers that were emasculated and crossed with pollen from White produced no fruits. This result at first glance would indicate a positive reaction to emasculation injury, but a careful examination of the flower remains indicated that the trouble lay with the pollen rather than with the treated flower.

All these results seem to point toward the fact that a few individual pistils of flowers of these otherwise self-sterile varieties will accept some pollen from the same flower in order to effect fertilization. With these self-sterile varieties, this phenomenon seems to be the sole remaining sexual means of perpetuation of the species in case of isolation.

With this explanation as to the cause of imperfect fruits, we get a better understanding of the real significance of the data in Table No. 1.

The varieties of dewberries then can be grouped into self-fertile and practically self-sterile classes, which are as follows: as self-fertile, we list the varieties, Austin, Cox, Ruth, and Lucretia; as self-sterile, Chestnut, Grandee, Limekiln, Haupt, Manatee, Munroe, Premo, Elijah No. 2, Rogers, San Jacinto, and White.

If now we turn to the column of species, we shall discover that all of the varieties that are self-sterile, with only two exceptions, fall into the species *Rubus trivialis*. It will be noticed that this species contains no self-fertile varieties, and this is a good indication that the species itself if self-sterile. The two self-sterile varieties that are not classified with this species are Haupt (a hybrid) and Premo, the only self-sterile variety of the species *Rubus villosus* that we are growing.

Of the self-fertile varieties, Cox and Ruth are hybrids, and Austin and Lucretia belong to the species *Rubus villosus*.

Growers of dewberries might well take more than a passing notice of this fact of sterility in dewberries, and make ample provision for cross-pollination of varieties to insure a bountiful crop of fruit.

Blackberries.—The self-sterility work with the blackberries began in the spring of 1910 and was continued through three successive seasons, ending with the year 1913. The tabulated results give a pretty clear idea as to which varieties are self-fertile and which are self-sterile.

Table No. 3

BLACKBERRIES.

Variety	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Blowers	41	38	3	0
Dallas	39	32	6	1
E. Cluster	34	33	1	0
E. Harvest	39	39	0	0
Eldorado	32	32	0	0
Illinois	31	30	1	0
Kenoyer	21	15	2	4
King	31	30	1	0
McDonald (hybrid)	45	0	0	45
Mersereau	31	31	0	0
Minnewaski	31	29	2	0
Rathbun (hybrid)	181	41	85	55
Snyder	30	28	0	2
Sorsby (hybrid)	28	0	0	28
Spalding (hybrid)	40	0	0	40
Wilson (hybrid)	41	40	0	1

Upon examination of the tabulated results, obtained under the same identical conditions of control as in the case of the dewberries, namely, the absolute exclusion of all foreign pollen from the bagged clusters, we notice that nearly all of the varieties are self-fertile, that one is imperfectly self-fertile, and that three are absolutely self-sterile.

Among the self-sterile varieties are Spalding, Sorsby, and McDonald; all three of which are hybrids between blackberries and dewberries. The imperfectly self-fertile variety, Rathbun, we also find to be a hybrid. All the rest of the varieties that are mentioned above are true blackberries and are self-fertile.

It may be said by way of explanation that in the above table those bags of blackberries that are listed as containing imperfect fruits differ essentially from similarly listed bags in the case of the dewberries in Table No. 1. The difference consists in the fact that in the case of the former the bags contained whole clusters of fruits which, although imperfect, were oftentimes large enough to be utilized in the harvesting and marketing of a crop. In the case of the dewberries, however, the bags contained fruits which, in number, averaged less than 10 per cent

of the total number of flowers inclosed, and whatever fruit was in evidence was composed of only a few (one to eight) druplets.

Even from the commercial standpoint, that variety which produced large numbers of imperfect fruits, as recorded in Table No. 3, cannot be classified with those which produced no fruit whatever, and therefore must be classified as being only imperfectly self-fertile.

By an examination of the records of the hybrids in Table No. 1, and in Table No. 2, we notice the interesting fact that among them fertility ranges all the way from absolute self-sterility, as in the case of McDonald, Sorsby, Spalding, and Haupt, through partial sterility, as in the case of Rathbun, up to complete self-fertility, as is found in the varieties of Cox, Ruth, and Wilson.

Sterility, from the evidence at hand, apparently occurs only in dewberries and their hybrids. Its cause, therefore, must be studied with the aid of dewberry and hybrid material. Blackberry varieties will henceforth in this bulletin be considered only in their relation as pollinators for the berry plantation.

THE PROBABLE CAUSE OF STERILITY.

Having determined the fact that some of our varieties of blackberry-dewberry and dewberry-blackberry hybrids, and some of our true dewberry varieties, are self-sterile, we shall now proceed to investigate the cause or the causes that might be responsible for this phenomenon of sterility.

Theories Advanced.

The investigations as to the causes of sterility will proceed along eight lines, or theories, which may be advanced as an explanation of this phenomenon. These eight theories may be stated as follows:

1. The factor of the origin of the varieties.
2. The structure of the flower, and disease (Double Blossom).
3. The daily blooming period of varieties.
4. The amount of pollen produced by the flower.
5. The factors of environment.
6. Sterility due to hybridism.
7. The percentage of defective pollen grains produced.
8. Natural antipathy between the pistils and the pollen of the same variety.

Experimental Evidence and Discussion.

Origin of Varieties.—From our results secured on the self-sterility and the self-fertility of varieties of dewberries, the fact becomes quite clear that the ancestral species of our cultivated varieties of dewberries fall into two well defined groups, namely, those that are self-sterile and those that generally are self fertile. The tabulated data in Table No. 1 reveals the fact that all of the varieties that are pure lineal descendants

of *Rubus trivialis,* and those varieties in which trivialis blood predominates, are self-sterile, while those varieties that come from *Rubus villosus* generally are self-fertile. Of this last named species, two varieties, Premo and Rathbun, prove to be exceptions under our observation. Premo exhibits absolute self-sterility, while Rathbun (a hybrid) is only partially self-fertile.

However, with only two varieties of *Rubus villosus* proving to be positively self-fertile, and one decidedly self-sterile, it was deemed expedient to test the species at large, that is, the wild species, before making any generalizations.

Rubus villosus is indigenous to our soil and climate, and the vines are to be found growing profusely and abundantly in and about our fields and woods. Accordingly, in the spring of 1915 twenty individual wild vines were marked, and on April 20th five clusters of flower buds on each of the vines were covered with cloth and paper bags.

If the species be self-sterile, we would find no fruits in the bags during the fruiting season; if the species be self-fertile, then we should expect to see a crop of berries in each of the undisturbed bags; if the species be composed of both self-fertile and self-sterile vines, then we should expect to get varying results. The following table shows the results of this test:

Table No. 4

Number of Vine	Species	Number of Bags Recovered	Number of Fruits	Number Without Fruits
No. 1	Villosus	4	4	0
No. 2	Villosus	4	2	2
No. 3	Villosus	4	3	1
No. 4	Villosus	1	0	1
No. 5	Villosus	5	0	5
No. 6	Villosus	5	4	1
No. 7	Villosus	3	2	1
No. 8	Villosus	5	4	1
No. 9	Villosus	4	2	2
No. 10	Villosus	9	9	0
No. 11	Villosus	10	10	0
No. 12	Villosus	9	9	0
No. 13	Villosus	5	5	0
No. 14	Villosus	7	6	1
No. 15	Villosus	11	11	0
No. 16	Villosus	14	3	11
No. 17	Villosus	4	4	0
No. 18	Villosus	5	4	1
No. 19	Villosus	5	5	0
No. 20	Villosus	5	5	0

From the tabulated results, the fact stands out very clearly that the species *Rubus villosus* at large is quite self-fertile. From this it is evident that the case of the variety Premo is simply an exception to the general rule, and requires special investigation.

It will be noticed that vines Nos. 4 and 5 record absolute self-sterility; but this sterility is undoubtedly due to the fact that the flower buds of these vines were far too small when they were inclosed. The same may be said about most if not all of the other buds that proved to be self-sterile. The proper time to inclose the buds is when the pink shows well on the expanding petals, and about one or two days before the bud may be expected to open.

Fig. 3.—Flowers of Manatee (dewberry) showing good cases of petalody.

Knowing, then, that the parental species of our cultivated varieties of dewberries are either self-fertile or self-sterile, we should anticipate finding similar characteristics respectively in the daughter vines, and with few exceptions such is the case.

The Structure of the Flower and Disease.—Petalody in the genus Rubus is by no means an unusual phenomenon, but when it occurs to such an extent and to such a high degree of development that it may endanger the normal functions of the essential organs of the flower,

then it becomes a vital factor in fruit production. This numerical increase in number of petals has developed to an unusual and to a very marked degree in the case of the variety Manatee.

Each of the plants of this variety was examined as to petalization, and each was found to produce blooms with both a normal and an abnormal number of petals. As the normal number of petals for the genus Rubus is five, any flower with more petals was considered petaliferous. The actual number of petals ranged all the way from five to twelve and fifteen. This condition of petalody is not peculiar to the variety Manatee, except in degree. Many other varieties are more or less affected, and notable among these are Chestnut and Elijah No. 2. Some of the flowers of Manatee are often so double as to resemble a small pink rose. In some years this abnormal condition of the bloom is much more pronounced than in others.

When many flowers of Manatee are bagged and allowed to be self-pollinated, we observe that frequently among them some will develop and bring to maturity a small number of druplets. This phenomenon has been observed in such other varieties as Chestnut, Grandee, Haupt, Rogers, and to a very limited extent in San Jacinto and in White.

When Manatee is cross-pollinated with other varieties of dewberries, fruits will develop, but the berries are very rarely perfect and well formed.

The reason that these berries seldom develop normally may be attributed to climatic or to soil conditions, for in Florida, where Manatee originated, the vines are said to produce an abundance of well formed fruits.

In order to ascertain whether Manatee is sterile because the extra number of petals really hindered pollen from reaching the stigmas of the pistils, five flower buds were bagged and pollen from Manatee flowers was artificially applied. Later, upon examination of these inclosed flowers, it was discovered that no fruits had set. The complete record of results follows:

Table No. 5

Number of Bags	Number of Flowers	Number of Perfect Fruits	Number of Nubbins	Number Sterile
No. 1	1	0	0	1
No. 2	1	0	0	1
No. 3	1	0	0	1
No. 4	1	0	0	1
No. 5	1	0	0	1

The results in the above table indicate that the excessive number of petals in the dewberry flowers does not necessarily constitute a mechanical obstruction to the process of pollination, but that Manatee is self-

sterile, notwithstanding the fact that its flowers frequently have an excessive number of petals.

If we carefully examine the flowers of our cultivated varieties of dewberries and hybrid blackberries we notice that two varieties, viz., Premo and Rathbun, show irregularities in the formation of their stamens. The flower buds of Premo are different from those of most other varieties of dewberries and blackberries in that the pistils rapidly elongate and protrude from the flower buds several days before the

Fig. 4.—Flower clusters of Premo (dewberry), showing how the pistils protrude from the bursting flower buds.

petals expand, and before the stamens mature. This apparently is a provision for securing cross-pollination.

Also, very often the stamens of the flowers are defective. Many of them never develop beyond mere rudimentary organs, some partly develop, others have their filaments dwarfed, and still others develop normal filaments but with anther sacks that are diseased and which liberate only defective or aborted pollen. The remaining stamens apparently produce normal pollen, but fruit will not set when the flowers are self-pollinated.

The flower of Rathbun is very similar to that of Premo except that the pistils do not protrude from the flower bud. When Rathbun flowers are self-pollinated we usually get some fruit development, and this fruit may range all the way from almost perfect to no fruit at all.

In regard to the question of self-sterility of varieties of dewberries, however, the fact still remains that in many other varieties with healthy normal stamens, complete self-sterility exists. Hence, another solution of the question of sterility must be sought.

Petalody in normal plants must not be confused in any way with Double Blossom (34th Ann. Rept. N. C. Agr. Exp. Sta., 1912, by

FIG. 5.—Flowers of Rathbun, (blackberry-dewberry hybrid), showing very much weakened and reduced stamens.

Reimer and Detjen and De; Agr. Exp. Sta. Bul. No. 93, by M. T. Cook), which is a disease that is caused by a parasitic fungus, *Fusarium rubi* (Winter).

This fungus is frequently the cause of the development of unusually large numbers of petals in the flowers of some varieties, notably, Lucretia and Wilson. In fact, some of the affected blooms quite resemble a small white double rose.

The real difference between a petaliferous bloom of a normal plant and a petaliferous bloom of one that is affected with *Fusarium rubi* is revealed in the production of fruit. Petaliferous flowers on otherwise

normal plants, when cross-pollinated with self-fertile varieties, very frequently set normal berries, while those petaliferous blooms which are the direct result of the action of fusarium very seldom if ever set fruit. The reason for this can be attributed to the destruction by the fungus of the essential organs in the flowers.

Sometimes, as in the case of the variety Manatee when cross-pollinated with pollen from self-sterile varieties, only nubbins are produced; however, this phenomenon is explained elsewhere in this bulletin, and will not be discussed at this point.

"Double Blossom" is not always revealed by the phenomenon of petalization. Many flowers that are apparently normal never set any fruit. In such cases only the sexual organs have been affected by fusarium, and consequently no fruit was produced. Careful examination of the flowers of all of our varieties that are affected with sterility, however, revealed only a very few traces of the disease.

The Daily Blooming Period.—In searching for the underlying cause of sterility in dewberries, it was deemed advisable to investigate the daily blooming period, and the relative time of dehiscence of the anther sacks. Flowers of *Rubus villosus* were observed opening at different times, some in the morning hours, some at noon, and still others in the afternoon. In fact, flowers in all stages of opening could be observed during all times of the day, depending, of course, upon the conditions of the weather.

Flowers of the different varieties of *Rubus trivialis* were observed to behave in a very similar fashion to those of *R. villosus;* hence the daily blooming periods of the two species, in this respect, are quite similar.

The anthers also were investigated as to the time of their dehiscence. It was found that in neither case did all of the anthers dehisce at the same time. Anthers sometimes burst before the petals expand, but in the majority of cases dehiscence begins after the flower has fully opened. The outer cycle of stamens first begins to shed its pollen, and the other or inner cycles follow in the order of their maturity. Generally speaking, twelve to twenty-four hours elapse before the last anther in the flowers has burst.

Because of this continuous shedding, a scarcity of pollen cannot be held responsible for the nonsetting of fruits, because any insect visiting such flowers cannot fail to become coated all over with the powdery element and transfer the same to other flowers.

Both species of dewberries were carefully observed in this respect, and as no difference in their behavior was found, we were forced to conclude that the daily blooming period and the time of the shedding of pollen has no effect on the general question of sterility.

The Amount of Pollen Produced.—By comparing the flowers of the self-fertile varieties with those of the self-sterile varieties, we observe at a glance that, with a few exceptions, the former produce far more pollen than the latter. This fact at once raises the question, Does the

small amount of pollen that is produced by some varieties account for the nonsetting of fruit?

In Table No. 6 is found the answer to this question. Pollen carefully gathered from the self-sterile varieties was actually applied by hand to the pistils of flowers of the same varieties, and no fruit was obtained. Therefore, the insufficiency of pollen production does not account for the absolute sterility of any variety of dewberries or of their hybrids.

Fig. 6.—Flowers of Lucretia (dewberry), showing well developed stamens.

However, in the growing of berry crops for commercial purposes we must bear in mind that the factor of pollen production is an important item. Insufficiency of pollen under these conditions may be the real cause of a crop failure, even although it will not account for the self-sterility of the variety. Because not enough of pollen is produced to satisfy the requirements of the pistils in all of the flowers of the whole field, the resultant crop is not only reduced in size, but also in quality, for the individual berries have suffered because a certain percentage

of its ovules did not receive the proper amount of pollen that is required for complete fertilization. Hence a large number of nubbins are produced instead of the well developed berries. The real cause of sterility, however, has not yet been reached.

Sterility Due to Environmental Conditions.—It is a fact that trees and plants which are generally self-fertile, under normal conditions, will produce an abundance of fruit, but which when subjected to abnormal conditions, such as a superfluity of moisture, an abnormal amount of nitrogen in the soil, late spring frosts, etc., will forego the production of fruit. In order to forestall any influences that might find their origin in the environs of the plants under our observation, the test plants in our experimental field were laid out in the following manner:

A square field, having approximately an area of two and one-half acres, was divided into two nearly equal parts, the division line extending from west to east. The northern half was devoted entirely to blackberries and blackberry-dewberry hybrids, and the southern half to dewberries and dewberry blackberry hybrids. Each half of the field was further subdivided into equal sized plats sufficiently large to accommodate three rows of each of the varieties with thirty plants to the row. The plants and the rows lie in a north and south direction. The distances between the plants in the rows, the rows from one another, and the spaces between the separate plants were made equal and uniformly at five feet. The whole field was laid off on the square system. Thus, the whole collection of test plats has the appearance of a regular fruit plantation. No especial care was exercised in the selection of varieties which were to occupy the successive plats of the plantation; however, it so happened, as was later discovered, that the self-fertile and the self-sterile varieties were pretty well mingled.

The square system of planting made possible the uniform cultivation of the individual plants in both directions, and made impossible unconscious differences in the treatment of the individual plats.

The soil of this berry plantation is a sandy loam underlaid with a clay subsoil and is as nearly uniform as it was possible to secure. Fertilizers were applied semiannually to the plantation as a whole, the phosphates and potash predominating in the spring application and the nitrogen element predominating in the summer application.

The cultivation of the individual plats consisted in the cultivation of the plantation as a whole; clean culture in the spring and summer, and a cover crop of rye or of cowpeas in the fall and winter. Thus the soil treatment accorded to one plat was accorded to all, and therefore the environment of one variety became, as nearly as was possible to make it, the environment of each and all other varieties.

If, then, the environment be the cause of the sterility of the different varieties, we should anticipate either sterility in all of the varieties or no sterility in any of them. It might be contended, however, that the conditions to which all of these varieties were subjected might be more

detrimental to some species or varieties than to others, and that for this reason varieties might behave differently. Allowing due credit for this fact, we nevertheless find that under normal conditions, and with varieties interplanted for cross-pollination, we get normal crops of fruit from all with the exception of Manatee. This fact is sufficient evidence that soil and soil-fertility factors must be separated and eliminated from the real causes that underlie the phenomenon of sterility of varieties in dewberries and dewberry hybrids.

Another factor of environment, namely, that of late spring frosts, must here be considered, because in this case the different varieties are not similarly affected. Some varieties of dewberries and hybrids are more subsceptible to cold than are some others.

Late spring frosts may destroy a berry crop in two different ways: first, by killing outright the succulent growth of vines that begin activity of growth during the early warm spells of late winter; and second, by the injury of the blooms of early flowering varieties. The crop of blooms for the season being destroyed, but very little fruit from such varieties can be expected during the following season.

Although all of the varieties of dewberries that have their origin in *Rubus trivialis* (and also the four hybrid varieties, Haupt, Sorsby, Spalding, and McDonald, which, from evidence derived from Table No. 1 prove to be self-fertile) belong to this group of early growers, and although it frequently happens that in this locality, as well as elsewhere, these varieties frequently have their crop of fruit considerably diminished by late spring frosts, the fact yet remains that during normal years these same varieties bring forth a bountiful supply of fruits. Thus, late spring frosts cannot be regarded as the cause of the general sterility of dewberries and their hybrid varieties.

Sterility Due to Hybridism.—That the mating of two widely separated species of plants or of animals frequently produces sterility in the offspring is a recognized fact. As an example, Dr. Peter Wylie in his report on the breeding of grapes wrote as follows: "We can impregnate the foreign (*Vitis vinifera*) with pollen from the Scruppernong, producing thereby only male (staminate) plants and imperfect hermaphrodite or pistillate plants, which bear no fruit." Again, all of Rogers' hybrids which are the offspring of native species of grapes crossed with pollen from *Vitis vinifera* are with only one exception self-sterile.

Any investigation as to the sterility of any variety of plants would be incomplete if it omitted altogether this important factor of ancestry.

By investigating the botanical characters of our cultivated varieties of dewberries we arrive at certain definite conclusions: First, that most of our cultivated varieties of dewberries, as near as we can ascertain, are direct lineal descendants from native species, and that but few are hybrids. Second, that generally the direct descendants of these native species retain the same relationship to the question of fertility exhibited by the parental species. An exception to this rule is found in the case

of the variety Premo, which presumably is a direct descendant from the self-fertile species *Rubus villosus*. Third, that true hybrids between self-fertile species of Rubus (examples of which are the varieties Cox, Ruth, and Wilson) may retain complete self-fertility, but sometimes only partial self-fertility, as in the case of Rathbun. Fourth, that true hybrids of Rubus species with self-sterile species may be self-sterile, examples of which are Haupt, Spalding, Sorsby, and possibly McDonald.

These hybrids are not self-sterile, however, because of the fact that they are of hybrid origin, but, rather, because sterility was imparted to them directly by one of their parents, presumably some variety of *Rubus trivialis*.

Since some of the varieties of true dewberries which show no hybrid origin are utterly incapable of setting fruit by themselves, we conclude that the true cause for the sterility of the dewberries and their hybrids must be sought elsewhere.

Amount of Defective Pollen (Miscroscopical Test)

TABLE NO. 6

PERCENTAGE OF NORMAL POLLEN GRAINS.

Variety	Species	Count Number 1	Count Number 2	Count Number 3
		Per Cent.	*Per Cent.*	*Per Cent.*
Austin	R. villosus	92.1	95.9	95.6
Chestnut	R. trivialis	73.5	77.9	83.7
Cox	Hybrid	78.6	76.8	83.7
Ruth	Hybrid		74.6	82.4
Grandee	R. trivialis	41.2	69.6	51.1
Limekiln	R. trivialis	93.4	92.0	91.3
Lucretia	R. villosus		92.7	95.8
Haupt	Hybrid	38.2	77.4	82.9
Manatee	R. trivialis	95.9	39.7	36.8
Munroe	R. trivialis	96.5	96.3	96.5
Premo	R. villosus		94.8	94.5
Elijah, No. 2	R. trivialis	78.0	96.3	93.2
Rogers	R. trivialis	94.5	91.9	92.5
San Jacinto	R. trivialis	68.9	79.6	91.7
White	R. trivialis	95.2	96.4	92.8
Spalding	Hybrid			56.4
Rathbun	Hybrid			57.5
McDonald	Hybrid			59.5
Sorsby	Hybrid			76.3
Wilson	Hybrid			53.2

The method used to secure the data in the above table was as follows: ten normal flowers, selected quite at random from different plants of the same variety, were used to supply the representative samples of pollen. The pollen from the ten flowers was shaken into a glass vial, thoroughly mixed by mechanical means, and then subjected to a miscroscopical examination. This examination consisted in counting and record-

ing of the total number of apparently perfect and the total number of defective pollen grains that were found in ten separate fields under the microscope. From these figures the percentages of good and of defective pollen grains were calculated.

This method of procedure was repeated for each variety, and the condition of its pollen determined. It must be stated that pollen grains which appeared normal regardless of actual viability were classed as good grains, and only small, hollow, and shriveled grains were counted as defective. With some varieties this distinction becomes somewhat difficult because of the production of a great many angular grains which closely resemble the defective ones.

From the tables we learn some interesting facts: first, that the self-sterile varieties of *Rubus villosus* produce a comparatively high (over 90%) percentage of normal pollen grains, and that Premo, the only lineal descendant grown here which does not produce such a quantity of normal pollen, is self-sterile; second, that the other self-sterile varieties, all of which, with the exception of the hybrids, are representative varieties of *Rubus trivialis,* vary considerably in the amount of defective pollen that they produce. Such varieties as Limekiln, Munroe, Rogers, and White produce a very small percentage of defective pollen, less than 8 per cent. In this respect they correspond very favorably with those varieties that are of Villosus origin and which are self-fertile. Other varieties of this same species, such as Chestnut, Manatee, and San Jacinto, show a very much larger per cent of defective pollen. With the exception of Manatee, these varieties produce approximately from 50 to 80 per cent of normal pollen. Manatee falls far below this class in that it sometimes produces as high as sixty and three-tenths (60.3) per cent and sometimes as high as ninety-four and one-tenth (94.1) per cent of defective pollen. All of these varieties are self-sterile. Cox and Ruth, two self-fertile varieties of hybrid origin, while perfectly self-fertile, produce as high as approximately twenty-two and three-tenths (22.3) per cent and twenty-five and four-tenths (25.4) per cent of defective pollen grains; while Haupt, a hybrid, which also produces an equally large amount of perfect pollen, is self-sterile.

From these results it becomes quite evident that the quantity or the number of defective pollen grains in the flowers of our self-sterile varieties of dewberries and hybrids plays no fundamental role in the cause of self-sterility of such varieties. The production of a comparatively high or a comparatively low percentage of defective pollen grains, however, becomes of vital importance to the commercial fruit grower in the selection of pollinators for the berry plantation. For, other conditions being equal, the greater the per cent of pollen produced, the greater are the chances for perfect cross-pollination and a "bumper" crop. The subject of the commercial importance of varieties which habitually produce a high per cent of perfect pollen will be discussed later under the subject of pollinators for the plantation.

Germination Test of Pollen.—Having discovered that self-sterile varieties of dewberries produce an abundance and in some cases, as high a percentage of morphologically normal pollen grains as any of those varieties that are self-fertile, the question of the viability of these apparently normal grains becomes of prime importance.

Pollen was gathered from all of the varieties, and subjected to a germination test in the laboratory by means of "hanging-drop" slides and germination solutions. The culture medium, as was discovered, might consist of either weak sugar solutions of varying strength, tap water, or even distilled water. Ordinary tap water was as good as any, and less troublesome to secure.

All of the examined slides disclosed the fact that the pollen grains which morphologicallly appeared normal were capable of a vigorous germination and growth, and that the self-sterility of varieties of dewberries is not caused by morphological defectiveness or a lack of viability in the pollen grains. Sterility has its seat in a more remote cause and requires further investigation.

Natural Antipathy Between Pistils and Pollen from the Same Variety.—Because self-sterile varieties of dewberries and their hybrids will, under normal conditions for cross-pollination, set an abundance of fruit, the fact is quite patent that the morphology of the pistils (stigma, style, and ovary) is quite normal, and apparently offers no explanation of the phenomenon of sterility. From the foregoing recorded results in regard to the viability of pollen from self-sterile varieties, and also from the good fruit crops secured under ordinary field conditions, we naturally draw the conclusion that the viability of the pollen grains is not responsible for the sterility of the variety. All of the essential organs of the flowers under certain conditions seem to function normally, and yet this phenomenon, self-sterility, does exist.

Whether in the case of self-pollination the pollen functions normally and the pistil behaves abnormally, or *vice versa,* or whether both organs refuse to act, has not been determined. At any rate, the antipathy between the pistil and pollen of the same variety seems to be the immediate cause for the failure of fruit setting, and therefore of self-sterility.

What this rather vague term, natural antipathy, really signifies—whether it is due to a toxic substance located in the pollen grain in the stigmatic secretions, style, or the ovules—remains yet to be discovered.

Viable pollen grains from a self-sterile variety, although ineffective on the pistils of flowers of the same variety, will bring about perfect fertilization when placed on the stigmas of another variety; and it matters little whether this second variety be self-fertile or self-sterile, of the same species or of another species (*Rubus villosus*).

The following table shows the results of extensive cross-pollination tests:

DEWBERRIES AND HYBRIDS.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
1911—					
White	San Jacinto	4	4	0	0
	Munroe	5	5	0	0
	Chestnut	6	6	0	0
	Limekiln	4	4	0	0
	Rogers	5	5	0	0
	Manatee	2	1	1	0
Limekiln	White	5	5	0	0
	San Jacinto	5	5	0	0
	Chestnut	5	5	0	0
	Manatee	5	3	1	1
	Rogers	5	5	0	0
	Munroe	5	5	0	0
Munroe	White	5	5	0	0
	San Jacinto	5	5	0	0
	Chestnut	4	4	0	0
	Limekiln	4	4	0	0
	Rogers	3	3	0	0
	Manatee	5	4	1	0
San Jacinto	White	4	4	0	0
	Munroe	5	5	0	0
	Chestnut	4	4	0	0
	Limekiln	5	5	0	0
	Rogers	4	4	0	0
	Manatee	5	5	0	0
Chestnut	White	5	5	0	0
	San Jacinto	4	4	0	0
	Munroe	4	4	0	0
	Limekiln	5	5	0	0
	Rogers	5	5	0	0
	Manatee	4	4	0	0
Rogers	White	4	4	0	0
	San Jacinto	4	4	0	0
	Munroe	5	5	0	0
	Chestnut	5	5	0	0
	Limekiln	5	5	0	0
	Manatee	3	3	0	0
Manatee	White	5	2	0	3
	San Jacinto	5	0	0	5
	Rogers	4	0	0	4
	Limekiln	3	0	1	2
	Munroe	5	0	1	4
	Chestnut	4	1	0	3
1912—					
Manatee	White	5	1	0	4
	San Jacinto	5	0	0	5
	Rogers	3	0	0	3
	Limekiln	4	0	0	4
	Munroe	5	0	0	5
	Chestnut	4	0	1	3
	Haupt	5	0	2	3
	Grandee	5	0	2	3
	Lucretia	8	8	0	0
	Cox	5	5	0	0
	Ruth	4	4	0	0

DEWBERRIES AND HYBRIDS—Continued.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
1915—					
San Jacinto	Lucretia	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Haupt	2	2	0	0
	Grandee	1	1	0	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Austin	2	2	0	0
	Manatee	2	0	2	0
	Check	1	0	1	0
Rogers	Chestnut	1	1	0	0
	Lucretia	2	2	0	0
	Elijah, No. 2	2	1	0	1
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Manatee	2	0	2	0
	Cox	2	2	0	0
	Austin	2	2	0	0
	Check	2	0	2	0
Elijah, No. 2	Lucretia	2	2	0	0
	White	2	2	0	0
	San Jacinto	2	2	0	0
	Rogers	2	2	0	0
	Premo	2	0	2	0
	Munroe	2	2	0	0
	Manatee	2	0	2	0
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Chestnut	2	2	0	0
	Austin	2	2	0	0
	Check	2	0	0	2
Manatee	Lucretia	1	1	0	0
	White	2	0	0	2
	San Jacinto	2	0	0	2
	Rogers	1	0	0	1
	Elijah, No. 2	2	0	1	1
	Premo	2	0	2	0
	Munroe	2	0	0	2
	Haupt	1	1	0	0
	Limekiln	2	0	0	2
	Grandee	2	0	1	1
	Ruth	2	2	0	0
	Cox	2	1	1	0
	Chestnut	2	0	1	1
	Austin	2	1	1	0
	Check	2	0	0	2
Munroe	Lucretia	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Haupt	2	1	1	0
	Grandee	2	1	0	1
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Austin	2	2	0	0
	Check	2	0	0	2
	Manatee	2	0	2	0

DEWBERRIES AND HYBRIDS—Continued.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Haupt	White	2	2	0	0
	San Jacinto	2	1	0	1
	Rogers	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Munroe	2	2	0	0
	Manatee	2	0	2	0
	Lucretia	2	2	0	0
	Limekiln	2	2	0	0
	Ruth	2	1	0	1
	Cox	2	2	0	0
	Chestnut	2	2	0	0
	Austin	4	4	0	0
	Check	2	0	0	2
White	Elijah, No. 2	2	2	0	0
	Haupt	2	2	0	0
	Lucretia	2	2	0	0
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Austin	2	2	0	0
	Manatee	2	0	2	0
	Check	1	0	0	1
Grandee	Lucretia	2	2	0	0
	White	2	1	1	0
	San Jacinto	2	1	0	0
	Rogers	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Premo	2	2	0	0
	Munroe	2	2	0	0
	Manatee	2	0	1	1
	Haupt	2	0	2	0
	Limekiln	2	2	0	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Chestnut	1	1	0	0
	Austin	2	2	0	0
	Check	3	0	2	1
Lucretia	White	2	0	1	1
	San Jacinto	2	2	0	0
	Rogers	2	2	0	0
	Elijah, No. 2	1	1	0	0
	Premo	2	2	0	0
	Munroe	2	2	0	0
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	0	2	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Chestnut	2	2	0	0
	Austin	2	2	0	0
	Manatee	4	0	3	1
	Check	2	0	0	2
Chestnut	Lucretia	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Haupt	2	2	0	0
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Austin	2	2	0	0

DEWBERRIES AND HYBRIDS—Continued.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Chestnut	Manatee	2	0	1	1
	Check	2	0	0	2
Austin	Lucretia	2	2	0	0
	White	2	1	1	0
	San Jacinto	2	0	2	0
	Rogers	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Premo	2	2	0	0
	Munroe	2	2	0	0
	Manatee	2	0	1	1
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	0	1	1
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Chestnut	2	2	0	0
	Check	4	0	0	4
Cox	Lucretia	2	2	0	0
	White	2	2	0	0
	San Jacinto	2	2	0	0
	Rogers	2	1	0	1
	Elijah, No. 2	2	2	0	0
	Premo	2	0	0	2
	Munroe	2	2	0	0
	Manatee	2	0	0	2
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Chestnut	2	2	0	0
	Austin	2	2	0	0
	Check	3	0	0	3
Premo	Lucretia	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Manatee	2	1	1	0
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Chestnut	2	2	0	0
	Austin	2	2	0	0
	Check	5	0	0	5
Ruth	Lucretia	2	2	0	0
	White	3	3	0	0
	San Jacinto	2	2	0	0
	Rogers	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Premo	2	1	0	0
	Munroe	2	1	1	0
	Manatee	2	0	2	0
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	2	0	0
	Cox	2	2	0	0
	Chestnut	2	2	0	0
	Austin	2	2	0	0
	Check	5	0	0	5
Limekiln	Manatee	2	0	1	1

From a study of the above tables we come to the following conclusions: first, that the pollen from the self-fertile varieties of *Rubus villosus* can fertilize the flowers of other self-fertile varieties of the same species; second, that the pollen from self fertile varieties of *Rubus vollosus* can fertilize the flowers of self-fertile varieties of the same species, and also, with the exception of the variety Manatee, those of the self-sterile species, *Rubus trivialis;* third, that the pollen from the self-fertile variety Premo can fertilize the self-sterile varieties of the same species, and, with the exception of Manatee, the self-fertile varieties of *Rubus trivialis;* fourth, that the self-sterile varieties of *Rubus trivialis* can fertilize all varieties of *Rubus villosus* and, with the variety Manatee excepted, the self-sterile varieties of *Rubus trivialis* and their hybrids; fifth, that the pollen from a self-sterile variety cannot fertilize the flowers of the same variety.

Consequently, the very interesting fact becomes evident that self-fertile varieties are not the only ones that can be used successfully as pollinators in a berry plantation, but that so far as viability of the pollen and fertilization is concerned, we can also use the recognized self sterile varieties. This fact, with the exception of Manatee, holds true, even though all of the varieties that are to be pollinated are self-sterile.

The variety Manatee presents a very unique case, and requires some words of explanation. From the information gained in Table No. 1, we learn that Manatee is practically a self-sterile variety. Frequently, however, under certain conditions of self-pollination, one to several druplets will be produced and will ripen. This condition, as has previously been stated, appears to be the result of self-fertilization. Other varieties of *Rubus trivialis* frequently behave similarly.

Manatee, when crossed with other varieties, behaves variously: generally speaking, it will not set much, if any, fruit when crossed with pollen from the self-sterile varieties of *Rubus trivialis.* When crossed with pollen from the self-fertile varieties of *Rubus villosus* some fruits will develop; but with us, Manatee growing in a mixed plantation never has set a paying crop of berries. As a pollinator for other varieties, therefore, Manatee is worthless, because the percentage of defective pollen produced by its flowers is so great that in a large berry plantation a dearth of viable pollen would be the result.

As has already been mentioned, the pollen of Manatee seems not to be very acceptable to flowers of other varieties of *Rubus trivialis,* for while in some years fairly good fruit was obtained in the hybridizing tests, yet in other seasons the resultant fruit crop was exceedingly poor, and in some cases no fruit at all was obtained. Neither is it very acceptable to varieties of *Rubus villosus.* Lucretia, Austin, Premo, and the self-fertile hybrids, Cox and Ruth, when pollinated with Manatee, show varying results. Of the varieties mentioned, Ruth seems to be able to use Manatee pollen to the best advantage, for the resultant fruit seems quite

normal in all external appearances. To sum it up, the variety Manatee has nothing to recommend it as a fruit producer, and still less as a general pollinator for other varieties.

POLLINATORS FOR THE BERRY PLANTATION

Although most of our important varieties of dewberries and blackberries are self-fertile, the crops might be considerably improved by the judicious selection of good pollinators. Pollinators not only serve to improve a crop, but, with many varieties, they are an actual necessity for the production of berries. Thus, all of the varieties that spring from the species *Rubus trivialis* need a pollinator in order to set a crop of fruit. Other varieties of dewberries are similarly affected, and the

Fig. 7.—Flower clusters of Snyder and King (blackberries), showing ample pollen production.

absence, in some cases, of a suitable pollinator practically means the total loss of a fruit crop.

Requirements of a Good Pollinator.—The requirements of a good pollinator are the following: first, self-fertility; second, a blooming period which is coincident with that of the variety to be pollinated; third, the production of an abundance of good viable pollen.

That self-fertile varieties are most desirable for pollinators becomes evident from the fact that during unfavorable weather conditions in the blooming season the flowers of such varieties are still able to set an abundance of fruit with the aid of their own pollen—they need not wait for insects to carry the pollen to them. On the other hand, with varieties not perfectly self-fertile, any condition which affects the activity of insects during the blooming season also affects the setting of fruit more or less seriously.

Dewberry and blackberry flowers differ somewhat from flowers in

general as regards to pollen production. Instead of all of the anthers bursting when the bloom opens, the anthers of the outer cycles alone dehisce first, followed gradually by the other cycles as they come to maturity. Flowers of this sort are not completely damaged by one rainstorm, because only the loose pollen is washed away, and when the weather clears up the anthers of the inner cycles mature and are ready to supply all the pollen needed by its own flower and the flowers that might be in the vicinity.

TABLE NO. 8

BLOOMING PERIODS OF DEWBERRIES AND BLACKBERRIES.

DEWBERRIES.

Variety	1910 First Bloom	1911 First Bloom	1915 First Bloom	1915 Last Bloom
Austin	Apr. 5	Apr. 17	Apr. 20	May 14
Chestnut	Apr. 4	Apr. 20	Apr. 19	May 24
Cox	Apr. 5	Apr. 20	Apr. 20	May 14
Ruth	Apr. 5	Apr. 21	Apr. 24	May 21
Grandee	Mar. 31	Apr. 20	Apr. 19	May 14
Limekiln	Mar. 31	Apr. 20	Apr. 20	May 20
Lucretia	Apr. 5	Apr. 21	Apr. 24	May 22
Haupt	----------	Apr. 28	Apr. 20	May 19
Manatee	Apr. 4	Apr. 14	Apr. 19	May 19
Munroe	Apr. 4	Apr. 17	Apr. 19	May 20
Premo	Apr. 5	Apr. 17	Apr. 24	May 16
Elijah, No. 2	Apr. —	Apr. 17	Apr. 15	May 19
Rogers	Apr. 4	Apr. 14	Apr. 12	May 14
San Jacinto	Apr. 4	Apr. 17	Apr. 15	May 14
White	Mar. 31	Apr. 17	Apr. 14	May 15

BLACKBERRIES.

Variety	1910 First Bloom	1911 First Bloom	1915 First Bloom	1915 Last Bloom
Blowers	May 1	Apr. 24	Apr. 29	May 21
Dallas	Apr. 28	Apr. 24	Apr. 25	May 20
E. Cluster	Apr. 22	May 1	----------	----------
E. Harvest	May 1	Apr. 24	Apr. 26	May 19
Eldorado	May 3	----------	Apr. 30	May 22
Illinois	May 1	----------	Apr. 30	May 21
Kenover	Apr. 29	Apr. 29	Apr. 26	May 19
King	May 3	Apr. 24	Apr. 29	May 22
McDonald	Apr. 8	Apr. 17	Apr. 20	May 13
Mersereau	Apr. 22	May 3	Apr. 29	May 22
Minnewaski	Apr. 22	May 1	Apr. 30	May 22
Rathbun	----------	May 1	Apr. 28	May 21
Snyder	May 3	Apr. 23	Apr. 29	May 22
Sorsby	Apr. 25	Apr. 22	Apr. 24	May 18
Spalding	Apr. 27	Apr. 20	Apr. 24	May 18
Wilson	Apr. 19	Apr. 23	Apr. 26	May 21

For best results, the blooming periods of the different varieties should be coincident so far as possible. This is especially true when only a very few varieties are under consideration. The earliest and the last blooms require a pollinator equally as potent as do those blooms from which the main crop is expected. In the consideration of several to

many varieties, which are intended to cover the whole fruiting season, it is necessary only to have the blooming period of some varieties overlap at all times, so that at no time in the booming season should we find but one variety in flower.

From the above table we learn that all of the earliest blooming dewberries belong to the species *Rubus trivialis,* which are self-sterile. Consequently, in selecting pollinators we must select such varieties as bloom at the same time, regardless of the fact that they are self-sterile.

The blooming period of dewberries lasts about four weeks. Straggling blooms may be found at all times during the fruiting season, but they may be safely disregarded, for there are not enough of them to warrant the time wasted in the gathering of the resultant fruits.

The blooming period for the blackberries seems to be a little shorter than that for the dewberries. Stragglers are here found mostly among the blackberry-dewberry hybrids, while the true blackberries seem to have a more definite blooming period.

Self-fertile vs. Self-sterile Varieties to be Used as Pollinators for the Berry Plantation.—From evidence disclosed elsewhere in this bulletin, it becomes evident that the requirements of pollinators need not necessarily hinge on the question of self-fertility of varieties, for we found that with one exception a self-sterile variety will readily cross with other self-sterile varieties; but the fact must be kept in mind that self-sterile varieties generally possess in a less degree the qualifications for a good pollinator; that self-fertile varieties will set fruit in bad as well as in good blooming seasons, and that the flowers of self-fertile varieties, whose blooming periods do not overlap, will nevertheless produce an abundance of perfect fruit, while those of the self-sterile varieties may not. For these reasons the self-fertile varieties of dewberries and hybrids that are grown either as dewberries or as blackberries ought to be given preference whenever possible in the selection of pollinators for the berry plantation.

Comparisons of Fruits from Self-fertilized and Cross-fertilized Flowers.—Leaving out of consideration the question of parthenocarpy, we find that in fruits generally those flowers that are cross-pollinated usually produce larger and better fruits than those that are self-pollinated. Whether this factor is of sufficient importance in the production of dewberries and of blackberries is a question worthy of consideration.

In order to investigate the probable effect of cross-pollination over that of self-pollination with varieties of dewberries and blackberries and their hybrids, two lots of flowers from each of two representative varieties of each type were selected. Lucretia and Austin were chosen to represent the dewberries; Early Harvest and Snyder, the blackberries; and Wilson and Cox, the hybrids. Each lot of the different varieties consisted of large branches with flowers clusters in as nearly the same stage of maturity as it was possible to find. All of these branches were covered alike with cloth bags; the first lot, in order to prevent cross-

pollination; and the second or check lot, in order to offset the effects of the covering in the first lot. The only difference in the resultant fruits must, then, be due to the origin of the pollen.

The flower clusters were covered, when possible, before any of the flower buds had opened, and such as had opened were carefully re-

Fig. 8.—A flower cluster of Munroe (dewberry), showing an abundance of strong, healthy stamens produced by a self-sterile variety of Rubus trivialis.

moved, so as to forestall any results due to activities of insects in their daily search for pollen and nectar. The bags covering the clusters of self-pollinated flowers were never lifted until comparisons of the inclosed fruits were made, while those bags which covered the cross-pollinated

flowers were lifted every day during the blooming season and the inclosed flowers crossed with pollen from other varieties until the last bloom was past the stage of receptivity. After this, these bags were also allowed to remain untouched until the inclosed fruits were ready for comparison.

Results and Discussion.—Of the dewberries, all of the bags were recovered. Both branches of each variety that was self-pollinated differed in no respect from similar branches that had been carefully crossed; nor did they differ from normal branches of fruit that were found in the open and had been left to insect pollination. The individual fruits were much alike in size, shape, color, and general condition.

With the hybrid vines, Wilson and Cox, similar results were obtained.

Fig. 9.—Lucretia dewberry (Rubus villosus). A good crop of dewberries produced by a self-fertile vine.

No deleterious effect of selfing was noticed. In the case of the blackberries, Snyder behaved in similar manner. Early Harvest produced two branches of good fruits and two branches of poor fruits; but it so happened that the "selfed" lot, like the "crossed" lot, produced one good branch and also one poor one. In this instance the poor development of fruit cannot be attributed to self-fertilization, but must be ascribed to some other unknown agent that attacked the branches of both plants alike.

It must be remembered, however, that in this experiment only known self-fertile varieties from each type were selected. Had we included partially self-sterile varieties or wholly self-sterile varieties, the results would have been most striking and to the contrary.

From these results we learn that by judicious and careful selection of varieties we may choose one or we may choose more than one variety for our fruit plantation and be reasonably certain of a good setting of fruit. However, under ordinary conditions, several varieties ought to be selected and mixed planting resorted to so as to secure the best possible results from cross-pollination. Cross-pollination causes no deleterious effects on the fruits, and usually is more beneficial in that a better crop may be produced.

In the case of the partially self-fertile varieties, such as Rathbun and of all the recognized self-sterile varieties of dewberries and blackberries a good pollinator is an absolute necessity.

SUMMARY

The results of the investigation as to the self-sterility of varieties of dewberries and of blackberries may be summarized as follows:

1. Among the fifteen varieties of dewberries that were tested for self-fertility, eleven were found to be self-sterile. These eleven varieties are as follows:

Chestnut	Haupt	Rogers	San Jacinto
Grandee	Manatee	Elijah, No. 2	White
Limekiln	Munroe	Premo	

The varieties that are found to be self-fertile are:

Austin	Cox
Ruth	Lucretia

2. Among the sixteen varieties of blackberries that were tested for self-fertility, three were found to be self-sterile, one partially self-sterile, and twelve self-fertile.

The self-fertile varieties are:

Blowers	Early Harvest	Kenoyer	Minnewaski
Dallas	Eldorado	King	Snyder
Early Cluster	Illinois	Mersereau	Wilson

The partially self-sterile variety is the hybrid Rathbun.

The self-sterile varieties are the hybrids:

McDonald
Sorsby
Spalding

3. That some flowers from varieties of dewberries which are here listed as being self-sterile, when self-pollinated, oftentimes produce a very few seeds; and that these seeds apparently are the direct result of self fertilization.

4. That the species *Rubus villosus* generally is self-fertile, but that self-sterile plants or varieties such as Premo, may not be uncommon.

5. That the species *Rubus trivialis,* judging from the results obtained from nine commercial varieties, is self-sterile; and that this self-sterility frequently is transmitted to its hybrid progeny.

6. That the self-sterility among dewberries and hybrid varieties that are grown either as dewberries or as blackberries can be attributed either to a nonattraction or to a repulsion of the sexual elements from the same plant or from the same variety.

7. That self-sterility of dewberry plants and of blackberry plants cannot be attributed to a want of viable pollen.

8. That pollen from most of the self-sterile varieties will successfully fertilize flowers on other self-sterile, or self-fertile varieties.

9. That fully self-fertile dewberry plants and blackberry plants, when self-pollinated, produce apparently as good fruits as when cross-pollinated.

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The members marked with * are members of the Joint Committee for Agricultural Work, and the Station is under their direction.

[1] In coöperation with the U. S. Department of Agriculture, Bureau of Plant Industry.

[2] In coöperation with the U. S. Department of Agriculture, Bureau of Soils.

[3] In coöperation with the U. S. Department of Agriculture, Bureau of Animal Industry.

[4] In coöperation with the U. S. Department of Agriculture, Office of Public Roads and Rural Engineering.

FOREWORD

Vitis rotundifolia, the Muscadine grape, has been the subject of investigation by the Department of Horticulture of the North Carolina Agricultural Experiment Station for a number of years, with a view to the determination and the discovery of facts relating to its origin, its characteristics, and the laws which govern their transmission. The results of such research should serve as an addition to our plant-breeding knowledge and help to form a substantial basis for the improvement of this class of grapes.

The results which have been accomplished are set forth in the following bulletins:

1. "Scuppernong and Other Muscadine Grapes: Their Origin and Importance," by F. C. Reimer, Bulletin No. 201, N. C. Agr. Exp. Station. 1909.

2. "Self-Sterility of the Scuppernong and Other Muscadine Grapes," by F. C. Reimer and L. R. Detjen, Bulletin No. 209, N. C. Agr. Exp. Station. 1910.

3. "Breeding Rotundifolia Grapes: A Study of Transmission of Character," by F. C. Reimer and L. R. Detjen, Technical Bulletin No. 10, N. C. Agr. Exp. Station. 1914.

The present bulletin deals with the problems of transmission of sex and constitutes the fourth contribution to this series of reports of work accomplished.

J. P. Pillsbury,
Horticulturist.

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INHERITANCE OF SEX IN VITIS ROTUNDIFOLIA

FIRST REPORT

By L. R. Detjen, Assistant Horticulturist.

I. Introduction

All commercial varieties of rotundifolia grapes of the present day are self-sterile. Because of this fact, staminate vines are required in the vineyards, especially true of large commercial vineyards, in order to produce profitable crops. Just what proportion of the vines should be staminate in order to insure maximum crops is at present an open question. As recommended by Reimer and Detjen (1)* one staminate vine should be planted for every eight fruit-bearing vines. This means that one vine out of every nine in the vineyard will bear no fruit, or, in other words, eleven and one-tenth per cent (11.1%) of the vineyard will be unproductive as far as fruit production is concerned. By planting staminate vines in the vineyard, land which is capable of producing fruit is given over to the production of pollen alone. Indispensable as pollen is, it is not the ultimate object of the fruit grower, and hence that land which is occupied by the staminate vines represents a direct loss.

By replacing each staminate vine with one which bears both pollen and fruit on the same vine, not only would pollen for cross-pollination be produced, but also a crop of fruit. Hence, if every ninth vine in the vineyard could thus be suddenly transformed from an indirect to a direct producer, the proceeds of the land might be increased eleven and one-tenth per cent.

If it were possible to replace all of our fruit-bearing varieties with self-fertile vines, ideal conditions respective to pollination would prevail in the vineyard. Each pistil in the flower would be surrounded by an abundance of pollen, and pollination itself would become independent of insect activities. Hence the crops of fruit would become more regular, irrespective of seasonal and climatic conditions, and the financial returns might be increased correspondingly.

*Reference to cited literature is made by number.

II. MORPHOLOGICAL DIFFERENCES IN THE FLOWERS OF VITIS ROTUNDIFOLIA

Grape flowers can be divided into three general classes or types:

1. The perfect hermaphrodite flower.
2. The staminate or "male" flower.
3. The imperfect hermaphrodite or "female" flower.

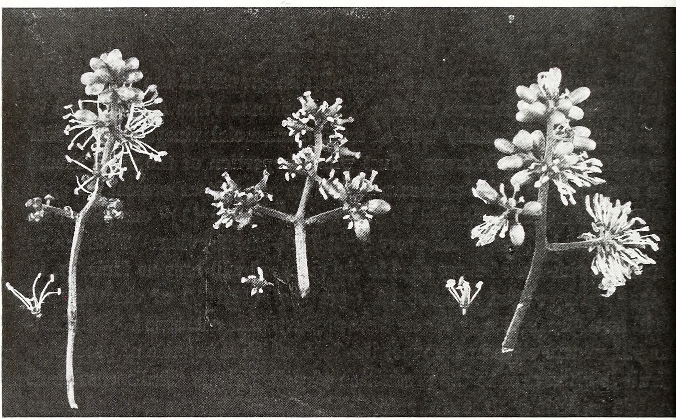

FIG. 1.—Three different types of flower clusters and flowers; on the left, staminate; in the middle, hermaphrodite with reflexed stamens; on the right, hermaphrodite with upright stamens. Natural size.

These types may be briefly described as follows:

After the petals, or "caps" as the united petals of a grape flower are called, have fallen, the perfect hermaphrodite flower consists essentially of a normal pistil and five or more upright stamens. Each pistil is functional and under proper conditions is capable of setting and developing a normal fruit. The stamens are strong and healthy. The filaments equal or exceed the combined length of the ovary, style, and stigma. They are stout and fairly symmetrically developed about their longitudinal axes. At the base of the ovary and between the stamens are situated the nectar glands, which secrete nectar, attractive to insects.

The staminate or "male" flowers are hermaphrodite flowers in which the pistils have been almost or wholly suppressed. It is almost superfluous to say that such flowers never produce fruit.

The imperfect hermaphrodite flowers are hermaphrodite flowers which are abnormal in one or more of the floral parts. In this type of flower the pistil has become more strongly developed by an enlargement of the ovary, a corresponding thickening of the style, and an enlargement of

the stigmatic surface. The stamens have undergone a marked transformation in both their form and usefulness. The filaments no longer stand truly upright, as do those in the normal flower, but are more or less recurved or reflexed. According to Dorsey (2), this is due to the unsymmetrical development about their longitudinal axes. In length and in diameter they have suffered material degeneration. Very often their length is considerably less than the greater diameter of the anthers, and their transverse diameter has been so reduced that the filaments bear very much of a resemblance to fine, silken threads. The pollen that is produced by these stamens, instead of being plump and smooth, appears shrunken under the microscope [Reimer and Detjen (1)], and, when seen in quantity, very much resembles a heap of dented and collapsed tennis balls. It is needless to say that such pollen is unviable under the best of conditions, and therefore absolutely worthless. Hedrick and Anthony (3) state that many varieties of grapes with the reflexed type of stamen produce some normal viable pollen grains among the usual misshapen and abortive kind. Such mixed pollen may yet be found with some varieties of rotundifolia grapes; but, to date, many varieties and seedlings of this species have been examined and no normal pollen has ever been found associated with the reflexed type of stamen. The nectar glands that are found in the flowers with the reflexed type of stamen are well developed; they secrete nectar and emit a very fragrant odor which is attractive to many insects.

Such, in general, are the characteristics of the three types of flowers in the genus *Vitis*. Intergrading types are often found, but these will receive special consideration elsewhere.

III. INTRODUCTION OF HERMAPHRODITE VINES WITH UPRIGHT STAMENS

In the Summer of 1910, while the study of self-sterility of Vitis rotundifolia was in progress, Professor F. C. Reimer (1) discovered a wild vine with upright stamens growing in a plum thicket about one mile from the city of Raleigh, N. C. At the time of the discovery the vine bore a fairly good crop of fruit and, although late in the season, a few flower clusters. It was the flowers on these clusters that commanded attention.

Bagging experiments conducted immediately upon the discovery of the vine gave results indicative of self-sterility. The more extended work of the following two seasons gave similar results.

Although the data obtained in the work of these three seasons pointed very strongly toward self-sterility, a belief in the self-fertility of the vine persisted and evidence secured in later years substantiated the correctness of this supposition.

The strongest evidence that was available in favor of the self-fertility of the vine was the fact that when it was discovered it bore a fairly good crop of fruit. While none of the flower clusters that were bagged in

the two succeeding years set fruit, neither did the flower clusters that grew out in the open produce any berries, although exposed to all chances for cross-pollination. Branches were also bagged and cross-pollinated with pollen from a light-colored staminate vine in order to test out the assumption that with this vine cross-pollination is absolutely necessary, but no fruit developed in any of these bags.

FIG. 2.—Lower section of a flowering branch of Hope. The two lower clusters have shed their stamens recently while the upper cluster is in full bloom. Reduced.

All of this evidence pointed not toward sterility because of defective pollen, but toward partial sterility, probably due to imperfectly developed pistils. The fact, however, that at one time a good crop of fruit had been produced was sufficient evidence that some day, perhaps, the vine might again return to fruitfulness, and this, as we shall see, has since happened.

In the meantime, as this vine was so full of promise, it was called "Hope," in commemoration of the hope and desire to find a self-fertile vine which might become the founder of a new race of rotundifolia grapes.

FIG. 3.—Two clusters of Hope. The cluster on the left is just beyond the blooming stage; note the number and the character of the pistils. The cluster on the right is in full bloom; note the upright stamens and the character of the pistils. Natural size.

Two other self-fertile seedlings, one a light-colored rotundifolia vine, origin not mentioned, and the other a dark-colored vine, a cross between Eden and a staminate vine, are reported by Husmann and Dearing (4).

These three vines are the only original ones mentioned as bearing flowers with upright stamens and with normal viable pollen. To these we look with confidence for the introduction and development of self-fertility among our varieties of rotundifolia grapes.

Description of the Hope vine; Floral Characters.—In general, the vine characters of Hope are typical of such as are found in the rotundifolia species. The plant is only moderately vigorous and is subject to the ravages of Black Rot (*Guignardia bidwellii*) in about the same degree as is the variety, Scuppernong. The main difference between this and other vines of the same species, however, lies in the floral characters. The flowers generally have neither the suppressed pistils of the staminate vines nor the recurved stamens of the common fruit-bearing vines, but they possess a combination of upright stamens with an abundance of healthy viable pollen, similar to that of typical staminate vines, and fairly well developed pistils, which upon fertilization are generally capable of developing into normal fruit. These pistils are not as large as those of other fruit-bearing varieties, neither is the stigma so well developed (Plate I, Fig. 2); still, the pistils are functional, and average sized fruit crops are often produced.

Occasionally, on some poorly nourished branch, which generally may be found on the lower or central portion of the vine, flower clusters are observed with some or all of the flowers representing various stages of development from the totally suppressed pistils of staminate flowers to the fairly well developed pistils of perfect flowers on other parts of the vine.

The filaments of the stamens in all of the flowers of this vine have the same strength, diameter, and upright position as do those in flowers of staminate vines. In short, the flowers of this vine might be termed staminate flowers whose pistils have reached a point in regeneration where they have become functional.

While the Hope vine is not as prolific in flower clusters as are some of our best staminate vines, nevertheless, it is quite representative of the average staminate vine. One or two flower clusters are usually produced on a cane, while three and four, although less often observed, are not at all of rare occurrence. Frequently, also, especially when the vine grows vigorously, many branches are produced which are absolutely barren.

The flower clusters of this vine are of fairly large size, considering the species. In fact, they are larger than those from the average staminate vine, and from external appearances, before the flowers begin to bloom, the clusters are seen to closely resemble those from a fairly good staminate vine. The number of buds on the cluster varies considerably, just as do those from all other vines. Countings made in the field place the number of buds per cluster anywhere between 100 and 300. Our best staminate vine produces clusters with buds ranging in number all the way from 200 to 384. It is probable that none of the fruit-bearing vines with reflxed stamens* produce clusters with more than 120 flowers,

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*Eden and San Monta are here excepted, because the former is considered a Munsoniana hybrid and the latter, supposedly a hybrid with a bunch grape, can probably be traced to a similar origin.

since the greatest number of flowers per cluster that has ever been recorded is 113. The vine which bore this cluster is a white fruited rotundifolia seedling found growing wild in the woods near West Raleigh, N. C.

FIG. 4.—A typical fruiting branch from the Hope vine. Note the small fruit clusters. Reduced.

The fruit clusters of Hope are very small; one, two, three, and four berries usually constituting the average cluster. One would think that a cluster bearing from 200 to 300 flowers ought to produce a fairly good-sized fruit cluster, but, contrary to expectation, only a very few berries

FIG. 5.—The largest cluster of fruit that was ever found on the Hope vine. The flowers of this cluster were not protected from cross-pollination. Natural size.

ever set on each of these clusters. The largest bunch of berries that was ever observed on this vine consisted of only ten berries, while the largest bunch of rotundifolia grapes ever observed by the writer was composed of thirty-five berries.* The number of berries per cluster varies with the general care of the vine.

The number of fruit clusters on the vine depends on many factors, among which the actual number of flower clusters produced, the degree of development of the pistils, and the amount of shedding that takes place soon after the flowers are fertilized are important items and demand consideration.

Self-fertility of Hope Vine.—In order to determine the exact status of the Hope vine in regard to the question of self-fertility, the following work was carried out:

In 1910, as soon as the vine was discovered, although this happened late in the season, two flower clusters which were still in bud were observed and immediately bagged. These bags were left undisturbed until all of the buds had bloomed, and later, upon examination of the contents of the bags, no fruit was found to have developed. The other parts of the vine bore an average crop of fruit which was produced from the normal flowers of the season.

In 1911 the experiment was repeated and, because of a greater supply of flower clusters, thirty-five branches were bagged and left to their fate. Not one of these thirty-five branches produced as much as a berry, but neither did the other parts of the vine bear any fruit.

In 1912 ten more branches, with two or more clusters to the branch, were covered. Although the vine bloomed profusely, no fruit was produced that year either in the bags or on the exposed branches of the vine.

In order to determine whether this vine failed to set fruit because of an existing uncongeniality between the pistils and the pollen of the same vine, or because of the lack of viable pollen, nineteen branches were bagged in 1911 and cross-pollinated with fresh pollen from a light-colored staminate vine. This pollen, although from a staminate vine, had no more effect on the setting of berries than did the pollen from the same vine, for no fruit was produced in the bags. The pistils, therefore, seemed to be faulty and incompetent to set fruit at times, regardless of the kind and source of pollen.

In 1913 only two berries were observed on the whole vine, and in 1914 only a handful, less than a dozen berries, constituted the total crop of fruit.

These negative results pointed very strongly toward sterility of the vine. It seems that for some unknown reason the vine appeared to have reverted all at once from a fruit-bearing vine to one that functions essentially as a staminate vine.

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*In 1914 a Luola vine produced an exceedingly heavy crop of fruit, and among the many large clusters one was found composed of 35 berries.

In the spring of 1911 a layer of this vine was transferred to the College grounds in order to have the vine under better observation and also to preserve the strain in case destruction should threaten the original vine. This precautionary measure was indeed a fortunate one, because during the spring of 1916 the original vine was destroyed by fire.

FIG. 6.—Two fruit clusters from the Hope vine whose flowers were protected from cross-pollination by having been inclosed in cloth bags. Natural size.

The layer that was transplanted to the vineyard grew well, and in 1912 ten branches were bagged before any buds had opened. Again, none of these flower clusters set fruit, and no fruit developed on the exposed branches of the vine.

In 1913 ten branches with a total of twenty flower clusters were carefully bagged, and this time eight of the ten bags contained some fruit. The whole vine had a fair sprinkling of fruit.

In 1914 twenty branches with not less than a total of forty clusters were bagged, and from each of these twenty bags some ripe fruit was harvested in the following September. The largest fruit cluster that was taken from these bags consisted of eight berries, while the largest cluster that was ever borne by the vine consisted of only ten berries.

In 1915 ten more branches with no less than twenty flower clusters were bagged, and fruit was harvested from eight of these bags in the fall of the year. Again there was a fair crop of fruit on the exposed parts of the vine, and every year since then a fairly good crop of fruit has been produced.

TABLE No. 1

A TEST OF SELF-FERTILITY OF HOPE VINE

Variety	Year	Number Branches Bagged	Number Bags Containing Fruit	Number Bags Containing No Fruit
Original vine, Hope	1910	2	0	2
	1911	35	0	35
	1912	10	0	10
Transplanted vine, Hope	1913	10	8	2
	1914	20	20	0
	1915	10	8	2

From the results of these bagging experiments we learn these important facts:

1. That the pollen of this vine, Hope, can under normal conditions fertilize the flowers on the same vine and on the same flower cluster.

2. That with proper cultivation and care this vine assumes the character of a hermaphrodite vine, while with neglect its pistils gradually cease to function and the vine assumes the general rôle of one that is staminate.

3. That cultivation, pruning, and general care exert a marked effect on the size and the regularity of the crop.

This last point is of considerable economic importance, because the general belief is that varieties of rotundifolia grapes can endure considerable neglect and still produce good crops.

IV. Investigations Regarding the Inheritance of Types of Flowers in Vitis Rotundifolia

With the discovery of the variety, Hope, we find that Vitis rotundifolia produces three distinct types of flowers instead of two. The important question now arises as to how and in what manner these three types of flowers are transmitted to the progeny of the first generation. Hedrick and Anthony (3), from tabulations of work done with many seedlings of Euvitis, report the following ratios:

Upright stamens × upright stamens=4.3 upright: 1 reflexed
Reflexed stamens × reflexed stamens=1.2 upright: 1 reflexed
Reflexed stamens × upright stamens=1. upright: 1 reflexed
Upright stamens × reflexed stamens=?

Whether these ratios are also representative of the laws that govern the transmission of types of flowers in Vitis rotundifolia is a question deemed worthy of investigation.

The method of procedure naturally resolves itself into a study of the progeny of crosses between vines with different types of flowers. Since there are flowers of three distinct types, namely, staminate flowers with upright stamens, hermaphrodite flowers with upright stamens, and hermaphrodite flowers with reflexed stamens, we may expect to make five different combinations, as follows:

1. Hermaphrodite flowers with reflexed stamens × staminate flowers (with upright stamens).
2. Hermaphrodite flowers with reflexed stamens × hermaphrodite flowers with upright stamens.
3. Hermaphrodite flowers with upright stamens × hermaphrodite flowers with upright stamens.
4. Hermaphrodite flowers with reflexed stamens × hermaphrodite flowers with reflexed stamens.
5. Hermaphrodite flowers with upright stamens × staminate flowers (with upright stamens).

The types of flowers that were observed in the progeny resulting from the first cross (hermaphrodite flowers with reflexed stamens × staminate flowers with upright stamens) has been partially discussed in Tech. Bul. No. 10 of this Station (5). Since that time more extensive and important data has been collected.

The following table shows the results so far obtained:

TABLE No. 2

SEX RATIOS AMONG PROGENY WHEN HERMAPHRODITE FLOWERS WITH REFLEXED STAMENS ARE CROSSED WITH STAMINATE FLOWERS

Female Parent	Male Parent	Number of Vines Staminate	Number of Vines Hermaphrodite With Reflexed Stamens	Number of Vines Hermaphrodite With Upright Stamens
Scuppernong	Light Male, No. 1	11	8	0
Scuppernong	Dark Male, No. 1	329	307	0
Scuppernong	Light Male, No. 2	507	494	0
James	Light Male, No. 2	59	64	0
Thomas	Light Male, No. 2	30	33	0
James	Light Male, No. 2	169	182	0
James	Light Male, No. 1	42	36	0
James	Light Male, No. 2	48	39	0
Flowers	Light Male, No. 2	103	82	0
Thomas	Light Male, No. 2	51	38	0
Scuppernong	Dark Male, No. 3	20	25	0
James	Dark Male, No. 3	9	6	0
James	Dark Male, No. 3	21	18	0
Thomas	Dark Male, No. 3	22	17	0
Latham	Light Male, No. 2	3	2	0
Thomas	Dark Male, No. 3	18	10	0
Thomas	Light Male, No. 2	15	14	0
Memory	Light Male, No. 2	5	6	0
Mish	Light Male, No. 2	2	2	0
Mish	Dark Male, No. 3	1	1	0
James	Light Male, No. 2	1	0	0
James	Light Male, No. 2	0	1	0
Scuppernong	Light Male, No. 2	4	2	0
Scuppernong	Light Male, No. 2	4	2	0
Seedling	Light Male	35	23	0
Totals		1,509	1,420	0

From the above table we learn two things: (1) That whenever hermaphrodite flowers with reflexed stamens are crossed with staminate flowers, only two tpes of flowers are observed in the progeny, namely, staminate flowers and hermaphrodite flowers with reflexed stamens (Plate I, Fig. 1, and Plate 2, Figs. 1-3). Not one seedling out of 2,929, representing the progeny of such a cross, has produced hermaphrodite flowers with upright stamens.* (2) That the ratio of the staminate flowers to the hermaphrodite flowers with the reflexed stamens is as 1509 :1420 or 105 : 1.

The second point under consideration is a study of the progeny resulting from hermaphrodite flowers with reflexed stamens when crossed with hermaphrodite flowers with upright stamens.

In 1911 five branches of a Scuppernong vine were bagged and later cross-pollinated with pollen from Hope as the male parent. In the

*Husmann and Dearing (4) report the finding of two fruit-bearing seedlings with upright stamens among the progeny of vines which bear the reflexed stamens when crossed with staminate vines.

following autumn a normal crop of fruit was gathered from these bags and a total of 108 seeds were harvested.

In 1912 the following similar crosses were made: Scuppernong × Hope, Thomas × Hope, and James × Hope. In each case the Hope vine was used as the staminate parent of the cross, and every cross seemed to be a congenial one, since a normal crop of fruit was harvested from these bags in the fall. A total of 1,351 seeds were obtained from the cross between Scuppernong and Hope, 1,117 seeds from the cross between Thomas and Hope, and 333 seeds from the cross between James and Hope.

In 1913 the variety Flowers was crossed with pollen from the Hope vine, and in all 309 seeds were harvested.

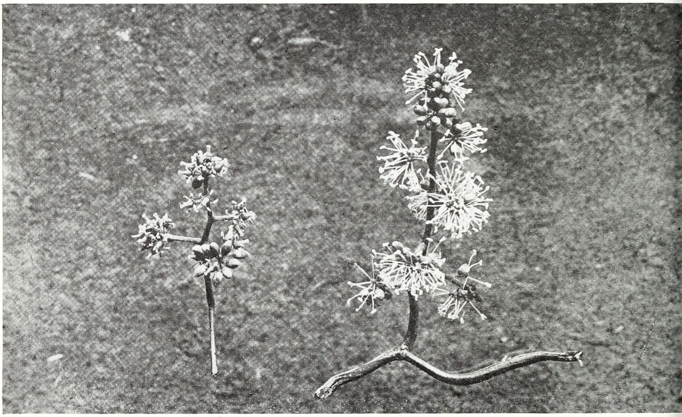

FIG. 7.—A flower cluster with reflexed stamens from a hermaphrodite vine and a flower cluster from a staminate vine. Note the comparative sizes and the characteristic type of each. Natural size.

In 1914 a light-colored seedling of James (F-13) was crossed with Hope and 149 seeds obtained. In the same year a dark seedling of Scuppernong (P-48) was crossed with pollen from Hope and 216 seeds obtained. All of these seeds were planted, and the resulting seedlings were later transplanted to nursery rows for study.

The following table gives the results obtained to date as to the different types of flowers that were observed among the progeny of the aforementioned crosses:

From this table we learn (1) that in every cross where Hope was used as the male parent on vines with reflexed stamens, only hermaphrodite vines have been obtained. Not one staminate vine has as yet appeared in any of these lots of seedlings.

TABLE No. 3.

SEX RATIOS AMONG THE PROGENY OF HERMAPHRODITE VINES WITH REFLEXED STAMENS CROSSED WITH HERMAPHRODITE VINES WITH UPRIGHT STAMENS

Year	Female Parent	Male Parent	Number of Seed-lings Surviving	Staminate Flowers	Hermaph-rodite Flowers Upright Stamens	Hermaph-rodite Flowers Reflexed Stamens	Sex Not Deter-mined
1911	Scuppernong	Hope	57	0	24	33	0
1912	Scuppernong	Hope	661	0	324	328	9
1912	Thomas	Hope	444	0	197	228	19
1912	James	Hope	158	0	79	74	5
1913	Flowers	Hope	104	0	39	53	12
	Totals		1,424	0	663	716	45

FIG. 8.—A typical hermaphrodite flower cluster with upright stamens. F_1 generation seedling of Thomas × Hope (three-year-old vine). Natural size.

By glancing at the record of the first lot, Scuppernong $\times$ Hope, the seeds of which were collected in 1911, we learn that of the 57 surviving vines, all are hermaphrodite in character and none are staminate.

In the second lot, where Scuppernong was again crossed with Hope, and seeds gathered in 1912, we see a repetition of the results that were obtained in the first lot, but in this case a much larger number of vines was involved. In the third, fourth, and fifth lots, in which Thomas, James, and Flowers were used to make similar crosses, the final results are practically the same. If we take the total of the numbers that were involved, we find that out of 1,424 vines, 1,379 produced hermaphrodite

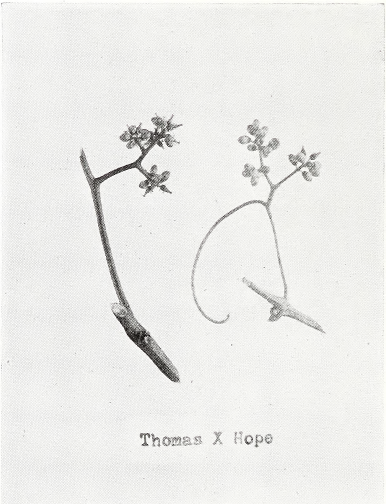

FIG. 9.—Two typical hermaphrodite flower clusters with reflexed stamens. F_1 generation seedling vine of Thomas $\times$ Hope (three-year-old vine). Natural size.

flowers, not one produced staminate flowers, and 45 were too weak to produce any flowers at all. These last mentioned vines unquestionably will also bear hermaphrodite flowers when mature.

We also learn (2) that these seedling hermaphrodite vines are of two kinds (Plate 1, Figs. 3-6), those which produce flowers with upright stamens and those which produce flowers with reflexed stamens. The ratio between these two floral types is quite uniform, and appears to be about equally divided. By adding the total numbers, we find that the upright stamen type is to the reflexed stamen type as 663:716, or a ratio of 1:1.07.

Fig. 10.—A typical flower cluster from the variety Flowers. Natural size.

Before drawing conclusions relative to the ratios existing between the different types of flowers, the utmost care should be exercised in getting as complete data as is possible, because very often hermaphrodite vines with the reflexed type of stamens are observed to require one or more years to reach full maturity than staminate, or hermaphrodite vines with upright stamens, This point is well illustrated in the following table.

TABLE No. 4

MISLEADING SEX RATIOS

Parentage	Age of Vines	Total Number Vines	Number Vines Blooming	Staminate Vines	Hermaphrodite Vines—Reflexed Stamens	Hermaphrodite Vines—Upright Stamens
Scuppernong × L. Male	2 years	51	18	16	2	0
Thomas × L. Male	2 years	72	31	23	8	0
James × L. Male	2 years	64	47	27	20	0
James × L. Male	2 years	63	31	17	14	0
Scuppernong × L. Male	2 years	128	66	55	11	0
Scuppernong × D. Male	2 years	644	198	143	55	0
Scuppernong × L. Male	2 years	832	176	157	19	0
Lab. Aest. × Lab. Male	2 years	65	19	19	0	0
Totals		1,919	586	457	129	0
Scuppernong × Hope	3 years	57	8	0	2	6
Scuppernong × Hope	2 years	661	79	0	18	61
Thomas × Hope	2 years	443	108	0	27	81
James × Hope	2 years	157	31	0	9	22
Total		1,318	226	0	56	170

From the first part of this table it becomes evident that the staminate vines in every case outnumber the hermaphrodite vines which bear the reflexed type of stamen, and that the ratio of the total number of such vines at the age of two years from seed is 457 staminate to 129 hermaphrodite vines with reflexed stamens, or 3.5 : 1. But there are still 1,333 vines which have not yet bloomed. It is necessary, therefore, that the types of flowers of all of these be considered before final conclusions are drawn.

The second part of the table shows the numbers of vines of the different types that bloomed at the age of two and three years when Hope was used as a male parent. Again, those plants that bear the upright stamens are in the majority, 170 vines with upright stamens as compared with 56 vines of the type that bears the reflexed stamens, or a ratio of 3 : 1.

Referring to Tables Nos. 2 and 3, we observe that when these same vines are three or more years of age the ratios of the vines that bear upright stamens to those that bear the reflexed stamens have been almost equaled. The ratios in both of these tables no longer stand as 3 : 1, but practically as 1 : 1, the theoretical ratio.

The third point under consideration deals with the ratio of the types of flowers that appear among seedling vines when both of the parent vines produce hermaphrodite flowers with upright stamens.

While testing the Hope vine for self-fertility, a certain number of seeds were secured from fruits that had developed in the cloth bags without the introduction of any foreign pollen. In 1913 sixty-eight seeds were thus secured and planted. From these 68 seeds only 7 plants

were obtained, of which, at the present writing, only 6 are alive. In 1915 two of these vines bloomed and each produced only staminate flowers.

In 1915, 47 seedlings were obtained from the same mother vine, and in 1916, 530 more seedlings from a similar origin but from different vines, were set in the nursery row for observation and study.

In the fall of 1913 a large number of seeds were taken from fruits of the Hope vine which had developed under natural conditions, that is, with the flowers uncovered and subject to any cross-pollination that might take place. From these seeds 142 plants were obtained and some of these have bloomed this year (1916). The types and numbers of vines that have bloomed and been observed are as follows: staminate vines, 21; hermaphrodite vines with upright stamens, 31; hermaphrodite vines with reflexed stamens, 4. The number of vines not blooming was 86. Of these 86 non-blooming vines, it was confidently expected by the writer that 17 vines, by virtue of their size and age, would produce hermaphrodite flowers with reflexed stamens. The remaining 59 seedlings were too small and weak to produce any flowers. If we accept the numbers of these vines as stated, the ratios of the different types is 21:31:21. What the final ratio will be when all of the vines shall have bloomed becomes, at most, an interesting matter for speculation.

TABLE No. 5

THE EXTENT OF NATURAL CROSSING THAT MAY TAKE PLACE AMONG THE SELF-FERTILE SEEDLING VINES OF THE HOPE VINE PROGENY WHEN GROWING IN MASS

Lot	Color Mother Vines	Total Number Seedlings Grown	Number Seedlings Light Color	Number Seedlings Dark Color
1	Light	112	110	2
2	Light	64	58	6
3	Light	59	55	4
4	Light	16	13	3
5	Light	105	88	17
6	Light	20	19	1
7	Light	104	104	0
8	Light	40	38	2
9	Light	96	90	6
Totals		616	575	41

In this work, seeds from light-colored vines only were selected, because, as the factor for coloration is dominant to its absence, the appearance of dark-colored seedlings in any of these several lots would be strong evidence in favor of cross-pollination.

From the evidence presented in Table No. 5, we learn that in eight out of nine lots of seedlings some dark-colored plants have appeared. By way of explanation, it should be said that the dark-colored vines, 547 in number, standing adjacent to the light-colored ones from which the

seeds were taken, were heterozygous for the light and the dark colors. If, then, any crossing took place between the light and the dark vines, the resultant dark-colored seedlings, according to the Mendelian laws, represent only about one-half of the actual number of such a cross. This very meager evidence gives us some idea of the actual amount of intercrossing that takes place among our strain of hermaphrodite vines that have the upright stamen. The ratios of colors that were obtained among these seedlings, however, are not to be taken as an index of the extent of cross-pollination that usually takes place among such seedling vines, but simply as an indication that some crossing has resulted.

The fourth point under consideration deals with the ratios between types of flowers among seedling vines when both of the parents bear reflexed stamens. Since Bul. No. 209 of this Station (1) discusses at some length the self-sterility and the inter-sterility of all rotundifolia grape vines which bear reflexed type of stamen, we understand immediately why such seedling vines have not been produced and, hence, why we cannot establish a ratio between types of flowers resulting from such a cross.

The fifth point under consideration deals with the ratios between types of flowers in the progeny when hermaphrodite flowers with upright stamens are crossed with staminate flowers. In 1915 twenty flower clusters of this Hope vine were carefully emasculated and bagged and later, after about twenty-four hours, viable pollen from a staminate vine was brushed over the pistils. No fruits developed in any of these bags.

The same spring 53 clusters on one of its self-fertile seedling vines were carefully emasculated and, when the pistils became receptive, were pollinated with fresh, viable pollen from a staminate vine. Not one of these flower clusters, however, has produced so much as a berry. At the same time, two large flower clusters on this same self-fertile vine, the flowers of which were not emasculated, were dusted with viable pollen from a staminate vine which is known to be homozygous for dark color. Eighteen berries ripened and a total of 61 seeds were obtained. These seeds were planted in 1916 and from them 59 seedlings were grown. Each of these 59 seedlings were light in color and not one was dark. This indicates that the seedlings were not the result of a cross between two separate vines, but the product from self-fertilized flowers on the mother vine, since dark color of vine is dominant over light color. [Reimer and Detjen (5), Hedrick and Anthony (3)].

In 1916 flowers of twelve more clusters from light-colored self-fertile seedlings were carefully emasculated and later hand pollinated with viable pollen from another staminate vine which is also known to be homozygous for dark color. Not one of these flower clusters produced a berry. At the same time the flowers on 50 or more clusters on similar light-colored, self-fertile seedling vines (all seedlings of Scuppernong and Hope) were emasculated, although less carefully in regard to the selfing of the flowers, and immediately cross-pollinated with pollen from a staminate vine which was known to be homozygous for dark color.

Of these 50 bags, 38 were later removed because they contained no fruits. Twelve bags contained one or more fruits, and from these 142 seeds were secured. These seeds will be duly planted, and the colors of the resulting seedlings were well watched with keen interest.*

V. CORRELATION BETWEEN TYPE OF STAMEN AND CHARACTER OF POLLEN AND BETWEEN SIZE OF FLOWER CLUSTER AND CHARACTER OF POLLEN.

The theory that the reflexed type of stamen in Vitis is usually associated with degenerate, impotent pollen, and with complete or nearly complete self-sterility, is generally conceded by most of the present-day investigators. In like manner the corollary of this theory, that upright stamens are generally an index of normal viable pollen and self-fertility, is also recognized [Dorsey (2), Hedrick and Anthony (3), and Beach (6)].

While this correlation between type of stamen and character of pollen holds quite true (Plates III and IV), the numerical relations that exist between viable and defective pollen grains in the same flower seem to be more or less variable.

Booth (7) says, in effect, that among garden varieties of grapes one can find, with the aid of a microscope, a whole series that produce more or less defective pollen. The percentage of this defective pollen in such varieties ranges all the way from almost none in the self-fertile varieties to 100 per cent in those that are self-sterile. What relation the amount of this defective pollen bears to the type of stamen by which it was produced, he does not make clear.

Hedrick and Anthony (3) have successfully crossed cultivated or garden varieties of *Euvitis* where both of the parents bore the reflexed type of stamen. The same authors have grown numbers of seedlings from such varieties when close pollinated, all of which goes to show that some normal pollen grains are frequently and habitually produced by some varieties that have the reflexed type of stamen.

While such varieties of grapes produce some viable pollen grains, not enough of these are formed, however, to class such vines among the perfectly self-fertile varieties. Barring the effects of ravaging diseases and other external factors, the looseness of a fruit cluster frequently is an indicator of the production of an insufficient amount of viable pollen for perfect fertilization. Most of the varieties with the reflexed type of stamen, however, are completely self-sterile, a fact which is due to their defective and degenerate pollen. This is probably more true of wild vines of the native species than of most garden varieties which are representative of hybridization and selection. Booth (7) says: "In

*Since the manuscript of this bulletin was prepared these 142 seeds have been planted and 39 seedlings have appeared above ground. Of these, 25 are dark in color and 14 are green. The dark seedlings, therefore, are the result of a cross between the light-colored and perfect flowered vine with upright stamens and a dark-colored staminate vine. Later on, these dark seedlings will be transplanted to the nursery row, and when grown the types of their flowers will be duly recorded.

the wild, the grape is diœcious, and fertile pollen borne by the pistillate flower with reflexed stamens is rare, if it occurs at all."

Among the many vines of Vitis rotundifolia, both the cultivated and the wild, that have been studied at this Station, not one case has been discovered where normal fruit is definitely known to have developed from pollen that was produced by the reflexed type of stamen.*

The production of seedless berries must naturally be omitted from the present discussion, because it is not the result of a sexual union between two normal gametes, and it is not the purpose of this bulletin to discuss parthenocarpy in relation to the pollination of flowers.

That all vines of Vitis rotundifolia which bear the reflexed type of stamen are completely self-sterile is borne out by the published results in Bul. No. 209 (1). To these results we can add from Tech. Bul. No. 10 (5), that when 693 seedlings were raised from Scuppernong crossed by a male vine homozygous for dark color, not one light-colored vine appeared in the whole lot. It will be remembered that in crossing varieties of rotundifolia grapes which have the reflexed type of stamen, the usual emasculation process is habitually omitted, because if any fertile pollen were produced, its presence could quickly be detected in the progeny of such a cross by the presence of light-colored seedlings. Likewise, the 62 seedlings from James crossed with the same dark male vine were all dark in color, notwithstanding the heterozygous nature of the James variety with respect to light and dark colors.

The correlation of upright stamens with viable pollen and self-fertility of the grape is also generally recognized. While the introduction of rotundifolia grape vines that bear upright stamens is of recent date [Reimer and Detjen (1), and Husmann and Dearing (4)], all have proved to be self-fertile, at least in varying degrees, and consistent with the small fruit clusters of this type of grape. Hope, our original wild vine, and its vegetative offspring, in some years under favorable conditions, has proven to be self-fertile, as recorded elsewhere in this bulletin.

All of the perfect flowered seedlings of this same vine, the founder of our race of self-fertile rotundifolia grape vines, also produce normal viable pollen like their parent and are self-fertile in the same degree.

Husmann and Dearing (4) report that both of their original seedlings with upright stamens are fruitful and self-fertile. Also, that all of their more recent seedlings of similar character are likewise self-fertile.

In 1915 flower clusters on a number of perfect flowered seedling vines were bagged for a test of their self-fertility. The bags happened to be distributed as follows: one bag on each of 64 different vines, six bags on one special vine, and eighteen on another special vine. The results obtained are presented in the following table.

*The two berries that are mentioned in Bul. 209 of this Station as having developed under closed cloth bags on a Scuppernong vine are regarded, in the light of more recent investigation, as the result of cross-pollination, which must have taken place previously to the bagging operation. That a single flower in the bag which covered several hundred similar flowers should receive sufficient pollen to produce three or four seeds, as was found in this case, while other flowers under the same bag by laws of chance should receive absolutely none, appears almost incredible. It is much easier to conceive of two fertilized blooms having been overlooked in the examination and preparation of the many thousands of buds that were covered in the experiment.

TABLE No. 6

SELF-FERTILITY OF HERMAPHRODITE SEEDLING VINES.

Parentage of Seedling Vine	Number Vines Repre-sented	Number Bags Used	Character Stamens	Number Bags Containing Fruit	Number Bags Without Fruit
James X Hope	20	20	Upright	11	9
Scuppernong X Hope	24	24	Upright	14	10
Thomas X Hope	20	20	Upright	9	11
Totals	64	64	Upright	34	30
Scuppernong X Hope	1	18	Upright	16	2
Thomas X Hope	1	6	Upright	5	1

In 1916 eight special vines were tested for self-fertility by placing ten bags at random on unopened flower clusters of each. The results that were obtained in this test are set forth in the following table:

TABLE No. 7.

SELF-FERTILITY OF HERMAPHRODITE SEEDLING VINES

Parentage	Number Branches Bagged	Character Stamens	Number Bags Containing Fruit	Number Bags Without Fruit
Flowers X Hope	10	Upright	0	10
Flowers X Hope	10	Upright	6	4
Flowers X Hope	10	Upright	3	7
Flowers X Hope	10	Upright	8	2
Thomas X Hope	10	Upright	0	10
Thomas X Hope	10	Upright	6	4
Thomas X Hope	10	Upright	0	10
Scuppernong X Hope	10	Upright	5	5
Total	80	Upright	28	52

In the two preceding tables we observe at a glance that in many cases fruit was produced and obtained without the aid of any cross-pollination. No such results have ever before been observed or obtained when flowers with reflexed stamens were isolated from chances of cross-pollination.

It will be observed, however, that not all of the vines which were included in this test produced fruits in the bags. This, however, is not a strange phenomenon when we consider the fact that each one of the sixty-four vines was represented by the flowers of only one or two clusters contained in only one bag. Even the eight vines on which ten and more clusters were bagged gave evidence that at times no fruits may set in some of the bags, and the vines still show signs of self-fertility by reason of the fruits that developed in the others. The failure of one or all clusters to produce fruit cannot well be regarded as proof of absolute sterility. Any one at all familiar with the rotundifolia species knows how common it is for young, vigorous vines to shed a great many of the

flower clusters without setting fruit when heavily pruned and crowded together as are these vines.

The point is well illustrated in the last table, where all of the eight vines shed some of their flower clusters, and three out of the eight produced no fruits at all inside of the bags. As the season of 1915 was an exceptionally unfavorable one for fruit production in the experimental vineyard, these negative results must be looked upon as indicative only, but a further trial or investigation doubtless will prove these same vines to be self-fertile like the others. All of the vines that set no fruit in the bags were subsequently examined as to the character of their pollen, and in no case did this prove to be anything but normal.

From these results we conclude that upright stamens in rotundifolia grape flowers are always associated with viable pollen, and, if the pistils are normally developed, with a certain degree of self-fertility of the vine.

It might be of interest to know that along with the character of the pollen, and the type of stamens, there is correlated a third character, namely, that of size of flower cluster. The staminate vines produce comparatively large flower clusters; the hermaphrodite vines that bear upright stamens produce flower clusters of a similar size, while the hermaphrodite vines with the reflexed stamens generally produce small flower clusters.

Notwithstanding the fact that the flower clusters of the three different types of vines vary considerably among themselves, it is always possible to determine with comparative ease and accuracy what the type of stamen and the character of pollen will be while the vine is still in bud.

When hermaphrodite vines that bear the reflexed type of stamen are crossed with staminate vines, the resulting progeny can be separated and grouped according to their sexes by means of the size of their respective flower clusters. In like manner the progeny of hermaphrodite vines that bear the reflexed type of stamen, when crossed with pollen from hermaphrodite vines that bear the upright stamens, can be separated and grouped according to the character of their pollen by nothing more than their characteristic flower clusters.

These correlated characters are of considerable importance to the rotundifolia grape breeder, because by means of them a comparatively early selection and segregation of vines can be made with respect to normal viable pollen and self-fertility.

VI. Similarity Between Flower Clusters That Are Borne on Hermaphrodite Vines With Upright Stamens and Those That Are Borne on Staminate Vines.

As the staminate vines when in bud, and before any flowers have opened, can be readily distinguished from the imperfect hermaphrodite vines by the difference in the size and shape of their respective flower clusters (see Fig. 7), so in like manner the perfect hermaphrodite vines

FIG. 11.—Two flower clusters from hermaphrodite vines of the F_1 generation of Flowers × Hope. The cluster on the right bears the upright type of stamen, while the cluster on the left bears the reflexed type of stamen. These two clusters are the largest of their kind that could be found among 103 vines. Natural size.

can be distinguished from the imperfect hermaphrodite vines (see Figs. 8, 9, 10, and 11). But a staminate vine and a perfect hermaphrodite vine when in bud cannot be so easily distinguished from one another, if at all.

A flower cluster on a perfect hermaphrodite vine, like one on a staminate vine, normally consists of a great many flowers crowded together on a more or less lengthened rachis (see Figs. 7, 8, 11, and 12). The largest number of buds that were ever counted in a single flower cluster on a staminate vine was 384 and on a perfect hermaphrodite vine (Hope) 299. This staminate vine, however, is one of the best ever observed by the writer among wild vines, while Hope is the first of its kind that was ever recorded among rotundifolia grape vines.

FIG. 12.—Variations in size of the flower clusters from hermaphrodite vines that bear the upright type of stamen. Natural size.

When perfect hermaphrodite vines become as plentiful as the staminate vines, then by virtue of a wider choice we can expect to find flower clusters on such vines equally as large as those on any staminate vine. Selected perfect hermaphrodite seedlings now in our possession doubtless will produce flower clusters equally as large as those that were observed on the staminate vine, but the average flower clusters on the average perfect hermaphrodite vines are about the same in size as those on similar staminate vines.

VII. The Probable Origin of the Hope Vine

By comparing descriptions of Hope with that of any staminate vine, one can readily see that the two have many things in common. Both vines produce pollen which, when mixed, cannot, by aid of the microscope alone, be distinguished as being the product from two different vines (Plate III, Figs. 1 and 3, and Plate IV, Figs. 1, 2, and 3); the pollen of both is viable and will germinate in sugar solutions; both produce upright stamens of identical size, shape, and appearance (see Figs. 3 and 7); and both produce large flower clusters typical of the staminate vines. The only point of difference lies in the fact that the Hope flowers possess functioning pistils which are not found in any staminate vine.

The seedlings of any hermaphrodite variety that has the reflexed type of stamen, when crossed with Hope as the male parent, are always hermaphrodite vines, but of two kinds: (1) those that bear the upright stamens, and (2) those that bear the reflexed stamens (see Figs. 8 and 9). These types occur in the expected ratio of 1:1, just as those whose male parent is a normal staminate vine. These perfect flowered seedling vines with upright stamens also come to maturity earlier than do those with the reflexed stamens, just as do normal staminate seedlings (see Table No. 4). The whole appearance and behavior of the Hope vine, and of its perfect flowered seedlings, with the exception of the regenerated and functioning pistils (Plate I, Figs. 2, 4, and 6), is that of a normal staminate vine.

Again, some of the flowers on the Hope vine and some on its perfect flowered progeny have been observed to be more or less intermediate between perfect hermaphrodite flowers and staminate flowers (Plate II, Figs. 4-9). Some of the pistils were dwarfed, some rudimentary, and some few were suppressed entirely (see Fig. 14), as is the case of staminate flowers. Such flowers were found to occur more abundantly on some vines than on others, but usually in all cases they were found on the lower and more poorly nourished branches of the vine.

All of this evidence points strongly toward the assumption that this Hope vine was primarily a staminate vine, with a staminate constitution, but one which from some unknown cause has undergone a partial regeneration of its pistils, some of which are able to function.

When flowers on many staminate vines are examined, it will be observed that there exists much variation in the size of the suppressed

FIG. 13.—Variation in the pistils of Vitis rotundifolia. Numbers 1 to 7, inclusive, represent the variations in the pistillate rudiments which were observed on different staminate vines. No. 8 shows the type of pistil that is found on hermaphrodite vines that bear the upright stamen. No. 9 shows the type of pistil that is found on hermaphrodite vines that bear the reflexed stamen. Natural size.

pistils (see Fig. 13, and Plate II, Figs. 1-3). In fact, many pistillate rudiments in flowers on staminate vines are larger than many similar rudiments in flowers on hermaphrodite vines. With this variation of the pistils in mind, it is not difficult to imagine that by a sudden release from an inhibiting factor these pistils, so long suppressed, have suddenly grown out and become functional.

FIG. 14.—Variations in size of the pistils frequently found on the hermaphrodite seedlings of Hope which bear the upright stamens. Cluster on the left represents the normal type of pistil, while cluster on the right shows considerable reduction in size of the pistils. Natural size.

The strongest link in the chain of evidence yet secured, which points out that the Hope vine is essentially a staminate vine with its suppressed pistils regenerated, lies in the evidence already submitted, to the effect that although fertile when treated with pollen from the same or similar flowers, these pistils are often unfertile when treated with pollen from a staminate vine.

Whether our race of self-fertile hermaphrodite vines represents a progressive step in the line of the evolution of rotundifolia grape flowers is a question that is not so easily proven. The fact that staminate vines show much variation in the size of the suppressed pistils, and that all of the hermaphrodite vines which function as pistillate vines bear stamens and pollen, although functionless, seems to indicate that early in the history of Vitis all of the vines bore hermaphrodite flowers whose stamens and pistils were perfect and functional. Considering the facts of the case in the light of our recent investigations, we may assume our original vine Hope to be a partial reversion to its ancient hermaphrodite ancestors.

VIII. SUMMARY

The investigations regarding the inheritance of self-fertility in Vitis rotundifolia which are being carried on at this Station have led to the following conclusions:

1. That Hope, the first discovered hermaphrodite grape vine of the species Vitis rotundifolia, which bears upright stamens, is self-fertile.
2. That the self-fertility of the Hope vine is variable, and seems to depend on its inner constitution.
3. That floral types in Vitis rotundifolia are transmitted to the progeny in definite ratios. Substituting S for staminate flowers, R for hermaphrodite flowers with reflexed stamens, and U for hermaphrodite flowers with upright stamens, we find that

$$R \times S = 1\,R : 1.06\,S$$
$$R \times U = 1.07\,R : 1\,U$$
$$U \times U = S : R \text{ (ratios not determined)}$$

4. That the Hope vine, and some of its self-fertile progeny, apparently will not cross with staminate vines.
5. That in Vitis rotundifolia the upright stamen in hermaphrodite flowers is correlated with normal, viable pollen, and self-fertility; that the reflexed stamen in hermaphrodite flowers is always associated with defective pollen and self-sterility.
6. That the Hope vine and all of its seedlings, which bear upright stamens, appear and behave essentially like staminate vines except for the facts that the flowers usually contain well developed pistils, and that fruit is subsequently produced.
7. That the Hope vine probably is a staminate vine whose long suppressed pistils have suddenly been regenerated and have recovered the power to function.

8. That the prototype of our present-day rotundifolia vines probably was a true and functioning hermaphrodite.

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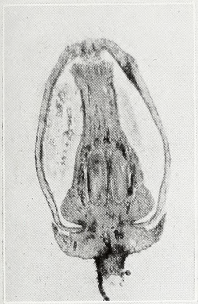
PLATE I

Photomicrographs of median sections of flower buds of Vitis rotundifolia

FIG. 1. Scuppernong
FIG. 2. Hope
FIG. 3. Hermaphrodite seedling with reflexed stamens F_1 generation of Scuppernong $\times$ Hope
FIG. 4. Hermaphrodite seedling with upright stamens F_1 generation of Scuppernong $\times$ Hope
FIG. 5. Hermaphrodite seedling with reflexed stamens F_1 generation of Thomas $\times$ Hope
FIG. 6. Hermaphrodite seedling with upright stamens F_1 generation of Thomas $\times$ Hope

PLATE I



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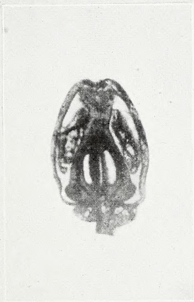

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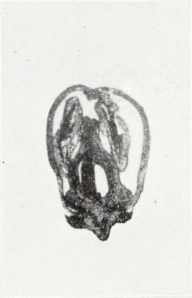

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PLATE II

Photomicrographs of median sections of flower buds of Vitis rotundifolia

FIG. 1. Staminate vine (S-10)
FIG. 2. Staminate vine (Light, No. 1)
FIG. 3. Staminate vine (D-21) showing rudiment of a style
FIG. 4-7. Hope, variations in the development of the pistils
FIG. 8. Pistillate rudiment found with some flowers on hermaphrodite vines that bear upright stamens, F_1 generation of Thomas $\times$ Hope
FIG. 9. Pistillate rudiment found with some flowers on hermaphrodite vines that bear the upright stamens, F_1 generation of Scuppernong $\times$ Hope

PLATE II

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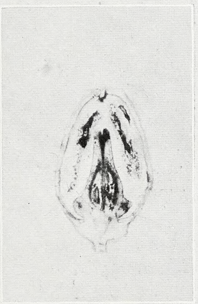

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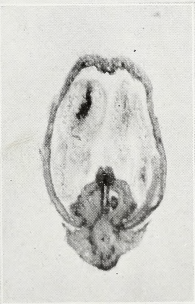

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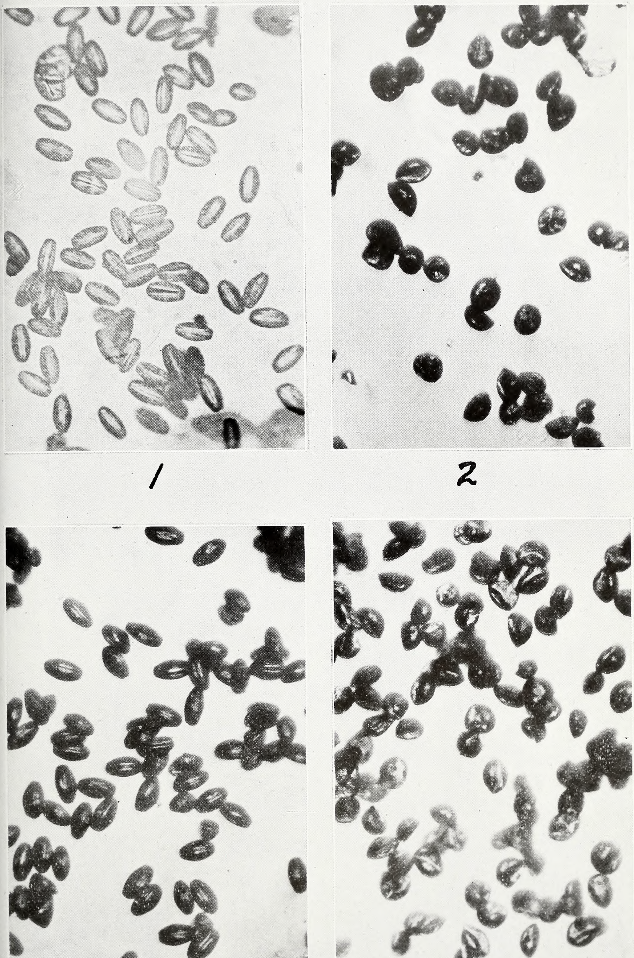
PLATE III

Photomicrographs of pollen grains of Vitis rotundifolia

FIG. 1. Pollen from Hope
FIG. 2. Pollen from Thomas
FIG. 3. Pollen from hermaphrodite seedling with upright stamens, F_1 generations of Thomas $\times$ Hope
FIG. 4. Pollen from hermaphrodite seedlings with reflexed stamens, F_1 generation of Thomas $\times$ Hope

PLATE III



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3 4

PLATE IV

Photomicrographs of pollen grains of Vitis rotundifolia

FIG. 1. Pollen from a staminate vine, Dark Male No. 1

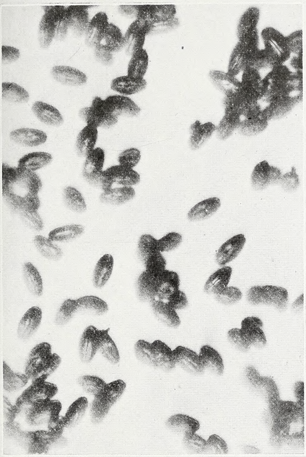
FIG. 2-4. Pollen from the three types of vines of the F_1 generation when Hope is selfed

FIG. 2. Pollen from a staminate vine

FIG. 3. Pollen from a hermaphrodite vine with upright stamens

FIG. 4. Pollen from a hermaphrodite vine with reflexed stamens

PLATE IV



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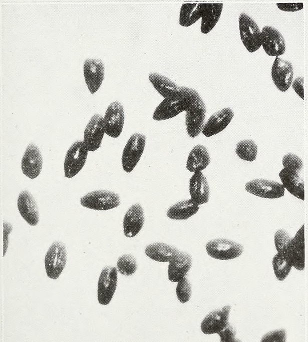

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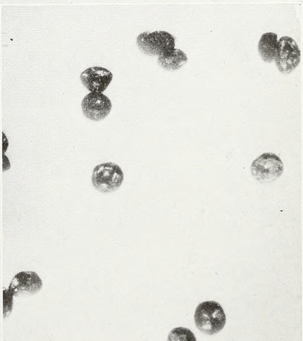

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RALEIGH AND WEST RALEIGH

BIOLOGICAL INVESTIGATION OF SPHENOPHORUS CALLOSUS OLIV.

Z. P. METCALF

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DESCRIPTION OF COLOR PLATE

Figure 1. Stalk of corn showing how the corn bill bug, feeding near the ground, eats holes in the leaves when they are rolled up, so that when they unroll rows of holes show across the leaf. Adult in normal feeding position.

Figure 2. Stalk of corn showing the stunting caused by the larvae working in the tap-root.

Figure 3. Corn bill bug laying egg in cornstalk.

Figure 4. Egg of corn bill bug, much enlarged.

Figure 5. Larva of corn bill bug, enlarged.

Figure 6. Larva in tunnel in tap-root of corn.

Figure 7. Pupa of corn bill bug, enlarged.

Figure 8. Adult corn bill bug, enlarged.


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PREFACE

The corn bill bug has long been recognized as one of the important insect enemies of corn in this State. Farmers generally are fairly well acquainted with its ravages, although, needless to say, it is not unusual to find the work of this insect confused with the work of other insects which injure the same parts of the plant.

Recognizing the importance of this pest and appreciating the lack of definite knowledge of this insect, Mr. R. I. Smith, then Entomologist of this Station, began an investigation of the corn bill bug in June, 1910, under an Adams Fund Project, entitled "A Biologic Study of the Species of the Genus Sphenophorus in North Carolina." Mr. Smith continued the investigation of this insect until he severed his connection with the Station in the fall of 1911. A report of Mr. Smith's investigations may be found in the Thirty-fifth Annual Report of the North Carolina Agricultural Experiment Station for the year ending June 30, 1912, pages 105 to 135.

The writer took up active work on the corn bill bug project when he was appointed Entomologist in the spring of 1912, and continued working actively on this project until the fall of 1915. Needless to say, the writer has drawn extensively upon Mr. Smith's paper in writing this bulletin, as Mr. Smith's work and the writer's have formed separate parts of one project. Mr. Smith's work was done largely in the laboratory and insectary. The writer's has been about equally divided between the laboratory and the field. Our results do not always coincide perfectly, due, perhaps, as much to methods and angle of approach as to any factor. Certainly, where conflicting reports are found it will be discovered on inspection that they are well within the probable error for such results.

This investigation has covered in all about five years, and while there are some phases of the question that are still undecided, it is thought that the investigation has reached such a stage that a report upon the biologic and economic aspects of the investigation is entirely justified, leaving a discussion of the other phases of the problem until another time.

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BIOLOGICAL INVESTIGATION OF SPHENOPHORUS CALLOSUS OLIV.

BY Z. P. METCALF

HISTORY, SYNONYMY, AND CLASSIFICATION

The corn bill bug (*Sphenophorus callosus Olivier*) belongs to the family *Curculionidæ*, the sub-family *Calandrinæ of the sub-order Rhynchophora.* This family includes various species of bill bugs proper, many of which are of economic importance in the United States, preying upon corn, grasses, etc., and the rice and granary weevils which feed upon various kinds of stored products and grains.

Blatchley and Leng (1916) describe the sub-family *Calandrinæ* as follows: "A rather small group of usually large, robust species, having the antennæ elbowed, inserted near the base of beak, their grooves very short, not receiving the scape; funicle 6-jointed, club not annulated, shining; labrum wanting; mouth cavity elongate, peduncle of mentum narrow, elongate, concealing the oral organs; mandibles compressed, with three apical teeth; beak variable in length and sculpture; thorax truncate in front and beneath, without ocular lobes; elytra without epipleurae and with a strong fold on inner face; abdomen with five ventral segments, the first and second longer, the third and fourth short, their sutures straight and deeply impressed, fifth equal to third and fourth fitting into the groove of the underside of elytra; last spiracle covered by the ventral segments; pygidium large, nearly perpendicular, exposed in both sexes; last dorsal of male quadrate and more or less retracted or concealed; coxæ all more or less separated, the hind ones transverse, oval; femora usually strongly clavate, not toothed; tibiæ short, not serrate, clawed at the outer angle; tarsi rarely brush-like beneath, third joint rarely bilobed; claws divergent, simple.

"The larvæ of the larger species bore into the stems of plants, especially grass and corn, while those of the smaller ones infest seeds and grain."

The genus *Sphenophorus* Schoenherr is world-wide in distribution, containing species that are of economic importance in several countries. It was described in 1837 by Schoenherr as follows:

Genus 390. Sphenophorus nobis.

Rhynchophorus Herbst. Schh. (1) Say—Calendra Clairville, Illiger, Germar; (2) Calandra Fabr. Olivier, Latreille, Germar, Dejean, Illiger, Oken, Sturm; (3) Curculio Linne et plures.

Character generis—Antennæ mediocres validiusculæ articulis duobus basalibus funiculi oblongis turbinato-obconicis, reliquis brevibus, sub- rotundatis omnibus distanibus clava breviter ovata, compressa, cuneiformis.

Rostrum elongatum, sub tenue, basi crassius, modice arcuatum, Thorax oblongus, antic angustior valde coarctatus, basi aut bi-sinuatus, aut rotundatus.

Elytra oblonga, sub ovata, apice in pleurisque singulatim rotundata, supra saepissime planiuscula.

Pedes mediocres, validi, longitudine sub aequales.

DESCRIPTION—Corpus elliptico-ovolum, supra aut planiusculum, aut paraum convexum, alatum, plerumque mediae magnitudinis. Antennae thoracis medium pertingentes, prope basim rostri insertae, validusculae, fractae, articulatae, scapo elongato thoracem apice attingente, sub-clavato; funiculo 6-articulato; articulis, 1, 2 oblongis, turbinato, obemicis, 3-6 in pleresque sub-rotundatis in caeteris sub-turbinatis, exterioribus successive parum crassioribus, omnibus distantibus; clava breviter ovata, compressa, cuneiformis bi-articulata; articulo 1° corneo, apice truncato, 2° spongroso, apice acetoto, aut truncato, aut sub-rotundato. Rostrum fere longitudine throacis, ante insertionem antennarum crassius dein sub-tenne, arcuatum, deflexum. Ocli lalerales, infra caput fere connexi, oblongi depressi. Thorax lalitudine baseos longior in plerisque bisinuatus, in allis rotundato productus, lateribus in plerumque basi sub-rectis, dein versus apicem porun rotundatis; anterius angustior, in nonnullis magnis aequaliter rotundatus, anticc subito angustior, semper longe intra apicem profunde, coaratus collun quasi annuliforme formans convexus. Scutellum triangulare. Elytra antice thoracis basi parum latiora et illa fere sesqui-longiora basi partim singulatim, sub-rotundata, partim conjunctium introsum rotundata—emarginata pone basim oblique ampliata dein posterius attenuata apice obtutus rotundata, aut sub-trunctata, abdomine breviora, supra in plerisque planiuscula in paucis nonnihil convexa. Pygidium sub-triangulare, deflexum. Pedes mediocres, longitudine sub-aequales validi; femoribus clavatis, saepissiare muticus raro sub-tusfixo, valido terminatis tarsi, elongatis, articula penultima, aut majusculo, subtus spongioso, out paulo minori subtus haud spongioso, unguiculari elongato clavato bi-inguiculata.

Typhus Sphenophorus abbreviatus.

(Patria Totus orbis; præsertim vero regiones calidæ.)

OBSERV—In numeroso hoc genere occurunt quedem species nonnulae, omnibus supra indicatis characteribus non exacte convenientes; dum vero notis generis maxime essentialibus correspondent, illas separare minus necesse censui. Inveniuntus elim aliae quarum forma corporis paulo convexior et tarsi diversimoda constructi pro quibus, ut interim saltem stirpem peculiaren assignavi.

Riley (1881) gives the following as the distinguishing characters of the genus:

"The distinguishing generic characters of *Sphenophorus* may be given briefly as follows: Side pieces of metasternum rather narrow; epimera of mesosternum externally truncate (not acute); front coxæ narrowly separated by the prosternum; third joint of the hind tarsi either glabrous or only pubescent on the sides. A peculiar external appearance will render the genus at once recognizable to the experienced eye, while the numerous species are very difficult to distinguish. The form of the tibia and tarsi and the vestiture of the latter have furnished excellent characters to divide the genus into natural groups. That to which our species (robustus) belongs is characterized as follows:"

Blatchley and Leng (1916) decribe the genus *Sphenophorus* as follows: "Rather large, robust, usually elliptic-ovate species, having the

body glabrous, often covered with a clayey artificial coat so as to hide the sculpture, more rarely with a dense natural glabrous coating; antennæ inserted near base of beak, scape long, slender, funicle six-jointed; club wedge-shaped, convex in front, the outer third of more sensitive; beak shorter than thorax, rather slender, feebly curved, swollen at base; antennal grooves very short, fovea-like, located close to eyes; thorax longer than wide, its disc usually with elevated smooth lines or spaces; elytra usually wider than thorax, their tips separately broadly rounded, thus widely exposing the pygidium."

The species that we are interested in was described by Olivier in 1807 as *Calandra callosa* from "Carolina," a region of great extent and including the greater part of the range of this species as we know it today. Olivier's description is as follows:

27 Calandra calleuse, Calandra callosa, Charauson, pl. 28 Fig. 416. C. d un noirgris obscur; elytres avec un point calleux lursant. C. obscura cincerascens, elytris puncto culloso nitido.

Antennæ nigræ apice cinero. Rostrum nigrum basi fusco-cinereum. Thorax fusco-cinereus obscurus dorso cruce vix elevata. Elytra haud striata subvariolosa fusco-cinerae obscura callo postico nitido. Corpus subtus pedesque fusco-cinerae obscura.

Tout le corps de cet insecte est d 'un noircendre obscur. Les antennes sont d 'un noir frun, luisant, avec le base condrec, obscura. Le corcelet est inegal et un voit a sa portie superceure une elevation en croix pen marquec les elytres sont inegales, presque variolees, marquecs, vers l'extremite d 'un point calleux presque epineux, noiratie, lursant.

Elle se trouve dons la caroline.

Du cabinet de M. Bosc.

In 1837 Schoenherr redescribes this species in his "Genera et Species curulionidum" as follows:

71 S. CALLOSUS OLIVIER.

Ellipticus, niger, opacus, indrimento fusco-cinereo, undique incustatus; thorace, inaequali, varioloso-punctato plagis tribus elevatioribus, natato media sub-cruciformi, elytris obsolete, remote punctato striatis, callo postico elevata nitido.

Calandra Callosa Oliv. Ent. V. 83, pp. 92, 27.

Patria America Septenbronalis.

This species seems not to have been referred to again until 1873, when Le Conte and Horn in their Rhynchophora of America North of Mexico unite this species with *S. cariosus* Oliv., stating their reasons for so doing as follows:

"Dr. Horn has suggested to me that this species and *S. callosus* Oliv. should be united. After careful examination of the specimens in my collection, I think this view is correct. Those who are inclined to adopt it will place *Callosus* as the synonym, since it is represented by old and abraded specimens."

S. callosus Oliv. was therefore considered a synonym of *S. cariosus* Oliv. until 1906, when Chittenden (1906) cleared up the situation by pointing out that callosus must be considered as distinct from cariosus. That portion of his paper which refers to callosus is as follows:

SPHENOPHORUS CALLOSUS OLIVIER.

Calandra callosa Oliver, Hist. Nat. des Ins., Vol. V., p. 92, Pl, XXVIII. Fig. 416, (1807).

Sphenophorus sculptilis Horn (nec Uhler). Proc. Am. Phil, Soc., p. 424 (1873).

This species was united by Le Conte and Horn with *cariosus*, but wrongly so, as I shall attempt to prove. Olivier's description reads in substance as follows:

"Body black with dark cinereous coating. Antennæ brownish black, shining, cinereous at apex. Rostrum black, *dark cinereous at base.* Thorax uneven, and one sees on the superior portion an elevation in the form of a cross, feebly marked." Elytra uneven, feebly variolate, marked toward the apex with a callous point, nearly spinose, blackish, shining.

"Olivier's illustration is imperfect in that it is very crude, showing neither punctuation nor sculpture, and the general impression is that of a shining species, which was certainly not intended. The thorax is a little short, otherwise the form coincides with the species which is figured herewith.

"The cinereous base of the rostrum is an important character, as it signifies that a considerable portion of the base is coated, while in *cariosus* it is not. The cross-like elevation of the thoracic disk is aptly described as *feebly* indicated; in fact, it requires little imagination to discern it in many individuals; moreover, it is not shown in Olivier's figure. In the true *cariosus* the cross is black, shining, and well marked, and the cariniform base of the third elytral interval which is always present is so prominent as to attract the attention of the veriest tyro.

"The type locality 'Carolina' will answer for either species. North Carolina appears to be the metropolis of *callosus*."

Blatchley and Leng (1916) described *Sphenophorus callosus* Oliv., as follows:

"Oval robust. Black, densely clothed with a brownish or olivaceous clayey coating; antennæ and tarsi reddish-brown. Beak two-thirds the length of thorax, compressed and sparsely punctate except near base, where it is swollen, coarsely punctate, and shallowly grooved above. Thorax slightly longer than wide, sides parallel from base for three-fourths their length, then strongly rounded to the constricted apex; disc very coarsely and irregularly punctate, the median vitta usually broadly dilated at middle, its apical portion very narrow; lateral vittæ broad at base and with a short oblique branch, their front portion often replaced by coarse punctures. Elytral oval, their surface uneven, sides gradually narrowed from humeri to apex; striæ fine, coarsely and distinctly punctate; intervals flat, their punctures hidden, the third sometimes feebly base. Humeral umbone and sub-apical callus somewhat prominent, often shining. Under surface coarsely and sparsely punctate. Length, 8-12 mm."

The synonym of this species would therefore seem to be as follows:

1807. *Calandra callosa* Olivier. Hist. Nat. des Ins. Vol. 5, p. 92, pl. 27, fig. 416.

1837. *Sphenophorus callosus* Olivier. Schoenherr Genera et species curculionidum, page 492.

1873. *Sphenophorus sculptilis* Horn (nec Uhler). Rhynchophora of America North of Mexico, page 424.

1873. *Sphenophorus cariosus* Le Conte and Horn. Rhynchophora of America North of Mexico, page 425.

1906. *Sphenophorus callosus* Chittenden. Proc. Ent. Soc., Wash. Vol. 7, pp. 166-182.

DISTRIBUTION

The distribution of the corn bill bug as recorded by Blatchley and Leng (1916) is as follows: Maine to Florida, westward to Arizona and northern Mexico and nothward to Wisconsin (Fig. 1).

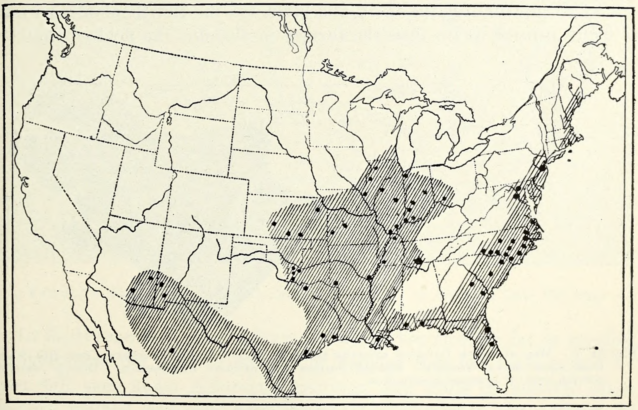


Figure 1. Map of the United States showing the distribution of the Southern Corn Bill Bug. Dots show recorded distribution. Shaded area approximate distribution. (In part after Webster.)

In this State it is largely confined to the region known as the Coastal Plain. This in a general way corresponds to the Lower Austrial Life Zone. Its distribution in the State as determined by the records of the United States Bureau of Entomology and the records in this office are shown graphically in Fig. 2. The dots show places where this insect has been found by field investigations or by correspondence. The shading indicates the approximate distribution of this species in the State.

In the map (Fig. 2) the area of especial destructiveness to corn is shown by double shading.

In the writer's experience, this insect is almost universally present in the eastern part of its range. In the western part of its range, however, it is confined to the low swampy situations along streams. This would indicate very strongly that the insect is very dependent upon soil with a great amount of water for its best development.

In the western part of its range it may be as abundant on cyperus as in similar situations in the eastern part of its range, and although corn is frequently planted in close proximity to such low swamps, the corn bill bug does not, so far as our observations go, turn its attentions from the cyperus to the corn.

DESTRUCTIVENESS

Probably no corn insect causes as great loss both directly and indirectly in the eastern part of this State as the corn bill bug. Complete destruction of entire fields is not only frequent, but common. Farmers frequently replant such fields in the hope of getting a stand, but it is not at all unusual for the third and often for the fourth planting to be so badly injured as to cause the farmer to abandon the field entirely.

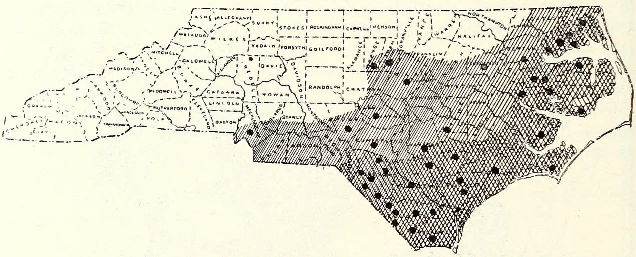


FIGURE 2. Map of North Carolina showing the distribution of the Southern Corn Bill Bug. Dots show actual records. Shaded portion approximate distribution. Doubly shaded portion area of greatest destruction.

As swamps are drained and put under cultivation the usual practice is to farm to corn for the first few years. The corn bill bug, driven from its natural food plant, turns its attention to the corn, and does so much damage that the growing of corn under such conditions is rendered entirely without profit.

A general conception of the appearance of such fields may be gathered from an examination of Figs. 3 and 4. In really serious cases of damage from this insect practically every stalk will be destroyed or only a stalk here and there will escape destruction. In cases of milder amount of damage more stalks will escape destruction, but a great many stalks will be so badly deformed that they make no satisfactory growth

and never produce ears. A few stalks more favorably located will make a fair growth and will stand above their neighbors like giants among dwarfs.

The very irregular growth of the stalks in the field is perhaps the best indication of the presence of the corn bill bug. Other indications are the rows of very regular holes across the leaves, and the presence of the adults clinging to the base of the stalk and the presence of the larvæ in the stalks and among the roots.

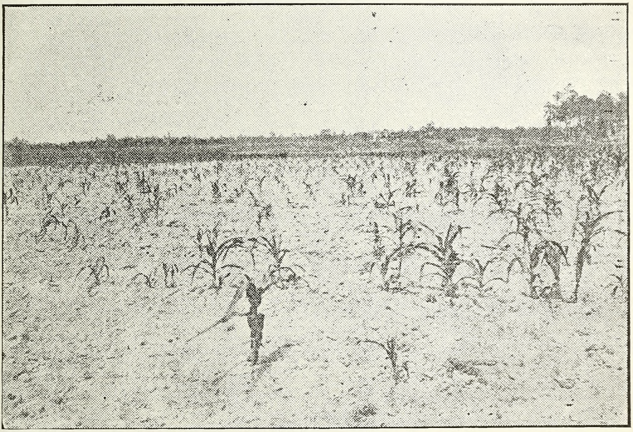
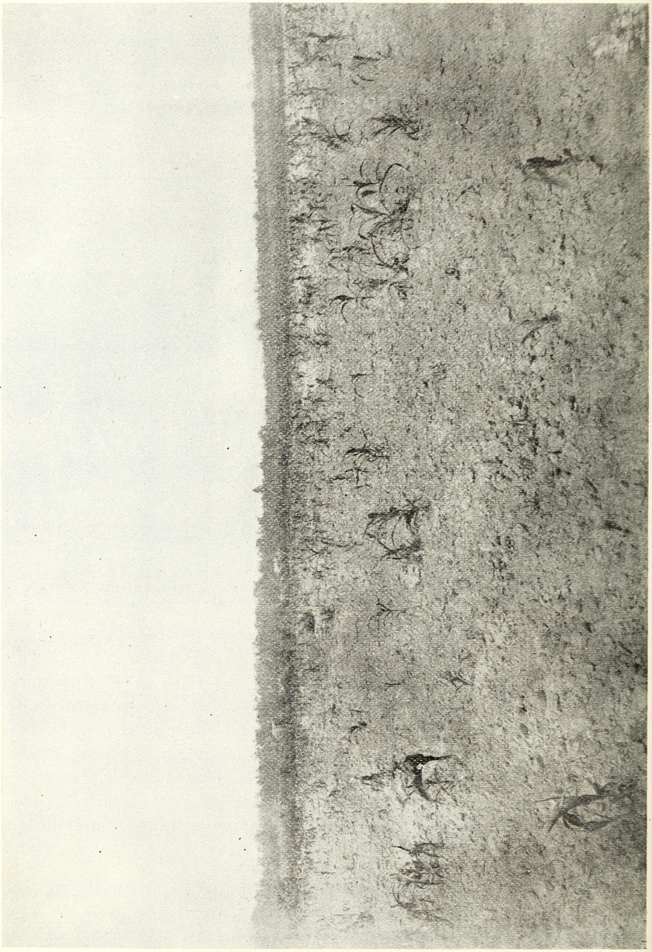


FIGURE 3. Field of corn, showing characteristic injury by Southern Corn Bill Bug.

In fields examined in this State the writer has tried as far as possible to determine the relative amount of damage that has been caused by corn bill bugs under different conditions, and while no entirely satisfactory method has ever been devised for expressing the amount of damage caused under different conditions in different fields, he has as far as possible tried to express this in a rate per cent, basing his conclusions upon a careful stalk-to-stalk examination of representative areas and also by a summary of the field as a whole after a careful survey.

Needless to say, a stalk-to-stalk inspection alone will not be an entirely satisfactory basis for estimating damage, for very frequently stalks are damaged so slightly by the adult beetles that the stalk will afterwards almost completely recover. This is especially true where the total number of beetles is small and the percentage of stalks damaged is relatively small.



COMMON NAMES

The southern corn bill bug has a large number of names in this State, the most common being derivatives of the name "Curlew Bug." The name "Curlew Bug" is given on account of its fancied resemblance to the Curlew. The curlew was a fairly common bird on our coast with a long curved bill resembling to a certain extent the snout of the corn bill bug. Some of the more common corruptions of the name "Curlew Bug" are "Klew" or "Clew Bug" and "Curlie Bug." It is also generally known as "bill bug" and "corn bill bug." The rice growers speak of it familiarly as "Rice Bug" and "Rice Bill Bug." In other sections it is known almost exclusively as "Chufa Bug" from its habit of feeding to a great extent upon the chufa. Other names may be used in various localities, but in the writer's experience these names are the ones most commonly used.

In this report the writer has adopted the name Southern Corn Bill Bug to distinguish it from other corn bill bugs found in other parts of the country. The writer feels that the selection of this name needs no special defense. He has selected it in place of the more common "Curlew Bug" for the reason that it calls to one's attention at once that this is the bill bug that is especially destructive to corn in the Southern States which the name curlew bug does not suggest.

INSECTS WHICH ARE OFTEN MISTAKEN FOR THE SOUTHERN CORN BILL BUG

There are in this State many different kinds of snout beetles, any one of which is apt to be mistaken by the farmer for the Southern Corn Bill Bug; but so far as the writer is aware, none of these snout beetles save the corn bill bug has the habit of feeding at the base of cornstalks, head downward. (Fig. 5.)

The work of various kinds of insects is often mistaken for the work of the corn bill bug. One of the most characteristic things about a plant injured by the adult Southern Corn Bill Bug is the presence of transverse rows of holes across the leaves. At least three other insects in this State also eat rows of holes across the leaves. These are the larger cornstalk-borer, the corn ear-worm, and the adult of the Southern corn root-worm. The work of the Southern Corn Bill Bug may be distinguished from the work of these three insects by its greater regularity. (Fig. 7.) This is due, no doubt, to the fact that the corn bill bug works well down at the base of the stalk in the "bud," whereas the other insects work in the top in the unfolding leaves. Of these three, the work of the larger corn stalk-borers on the unfolding leaves resembles most closely the work of the corn bill bugs. The work of the stalk-borer is never quite so regular, however, as the corn bill bug's work, and frequently the rows of holes are only on one side of the heavy mid-rib, whereas in the case of the corn bill bug they are on both

sides of the leaves and usually they are of almost the same size and shape on both sides of the leaf. The holes eaten by the corn bill bug are nearly always with smooth round edges, as if they had been cut

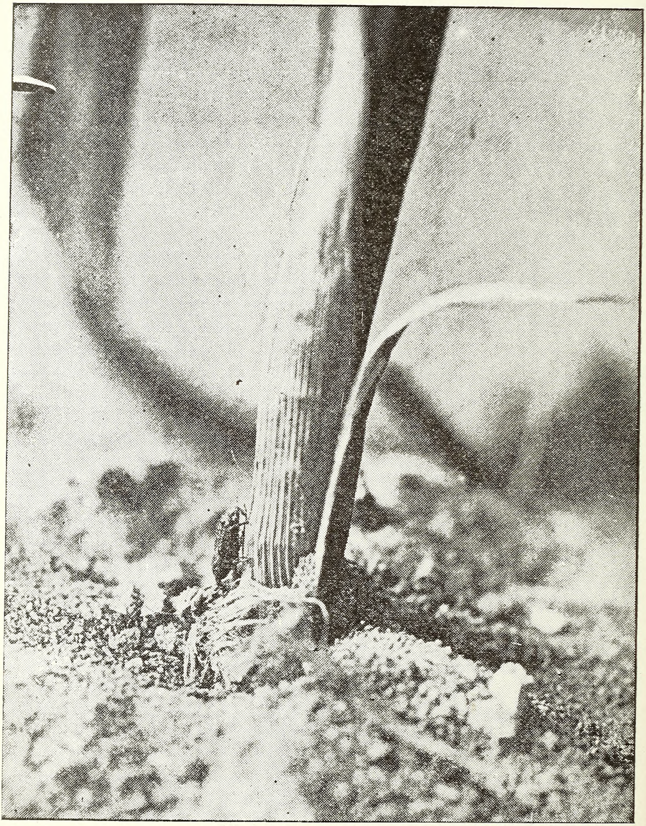


FIGURE 5. Adult Southern Corn Bill Bug feeding on corn, normal position.

with a sharp punch, while the holes eaten out by the corn stalk-borer are usually decidedly more ragged. The holes eaten by the corn earworm are usually not round, but elongate and decidedly more irregular, on the average, than the holes made by the corn stalk-borer. The holes

eaten by the adults of the southern corn root-worm have a tendency to be square instead of being round. Not infrequently these beetles eat the tender leaves just above the seed leaf until the unfolding leaves are completely cut off. In this respect their work resembles the work of certain cut-worms, species not determined, which have the habit of

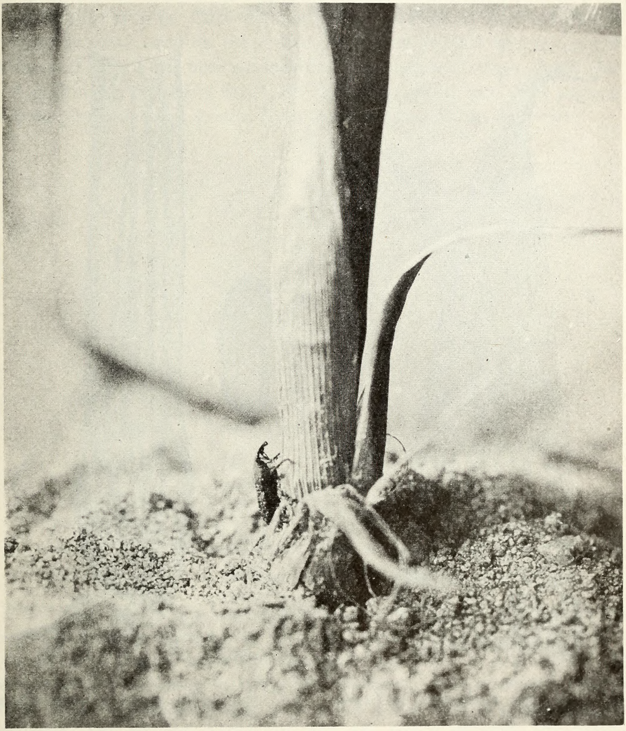


FIGURE 6. Adult female Southern Corn Bill Bug ovipositing in corn, normal position.

crawling up the stalk and cutting off the unfolding leaves. In all the fields examined, however, the work of the adult root-worms was much more common than the work of the cut-worms.

In general, farmers do not distinguish clearly between the work of the adult corn bill bugs on young corn and the work of the southern corn root-worm. The work of the corn root-worm is most conspicuous

about the time the corn is sprouting. At this time the seed leaf is vigorous and green and the unfolding leaves (bud) are withered and dead in those stalks that have been attacked by the root-worm. (Fig. 9.) On the other hand, in stalks attacked by the corn bill bugs all the leaves remain fresh and green at this time and later the whole plant dies if it is severely attacked. These young stalks usually show the characteristic rows of holes acoss the leaves. (Fig. 10.)

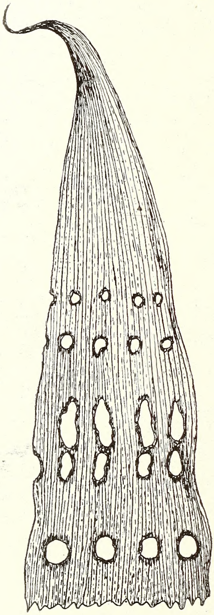


FIGURE 7. Portion of a corn leaf showing characteristic arrangement of feeding punctures.

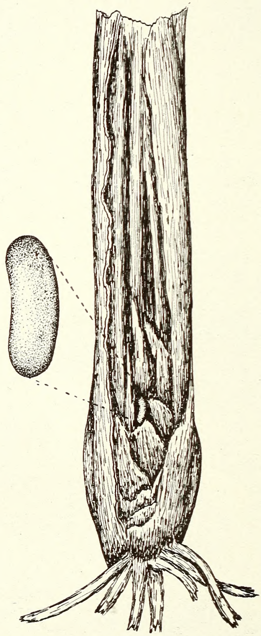


FIGURE 8. Young corn stalk showing normal position of egg in heart, and egg more enlarged.

FOOD PLANTS

The following plants have been found infested with the corn bill bug. Corn, rice, and various species of cyperus as follows:

Cyperus flaricomus, at Raleigh and Willard,
Cyperus cylindricus, at Proctorville and Braswell,
Cyperus strigosus, at Lumberton and Chadbourn,
Cyperus overlaris, at Pembroke,
Cyperus esculentus (Chufa).

Of these plants, corn, rice, and chufas are infested wherever they are grown in the bill-bug section of the State, so far as we have observed. Of these plants, rice seems to be the favorite food where it can be secured, followed by chufas and corn. The reason for placing chufas ahead of corn is that around Raleigh, so far as observed, bill bugs are plentiful on chufas, but do not trouble corn even when they are growing side by side. The various species of cyperus will undoubtedly have to be considered as the native food plant of this species in spite of the fact that it has been reared from other grasses (Figs. 11, 12, 13).

According to Webster (1912), the following plants have been reported as food plants for this species from various parts of the country:

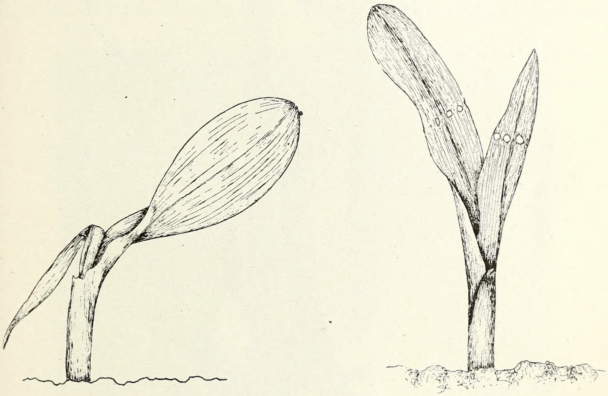


FIGURE 9. Young corn plant showing injury by Southern Corn Root Worm.

FIGURE 10. Young corn plant showing injury by Southern Corn Bill Bug.

"Dr. Forbes gives *Cyperus strigosus* as the natural food plant, in the roots of which it develops in Illinois. Mr. T. D. Urbahns found it developing in *Tripsacum dactyloides* at Plano, Tex., in July, 1909. At Appleton, Tenn., July 14, 1911, Mr. George G. Ainslie found the infested fields in part grown up with weeds and a swamp carex (*C. vulpinoidæ*), but he was unable to find the beetle actually developing therein. (See Pl. IX, figs. 1, 2.) Mr. A. N. Caudell reported the larvæ injuring the roots of yellow nut-grass (*Cyperus esculentus*) at Stillwater, Okla., in 1895. Dr. Chittenden reared the adult from a pupa found in the roots of *Panicum capillare* growing in low bottom-lands along the canal near Glen Echo, Md., in August, 1897. Mr. I. J. Condit found it breeding in Frank's sedge (*Carex frankii*) growing on the Department farm at Arlington, Va. In Florida the insect develops from egg to adult in *Cyperus rotundatus,* while farther north, in the

Carolinas, the common food plant is the "chufa" (*Cyperus esculentus*). To such a degree is this true in the latter locality that the insect is supposed by farmers to have been introduced with that plant. Quite in accord with the foregoing, Mr. J. G. Sanders reared adults March 30, and again April 25, 1908, from *Cyperus exaltatus,* introduced from Egypt and growing on the Department farm at Arlington, Va."

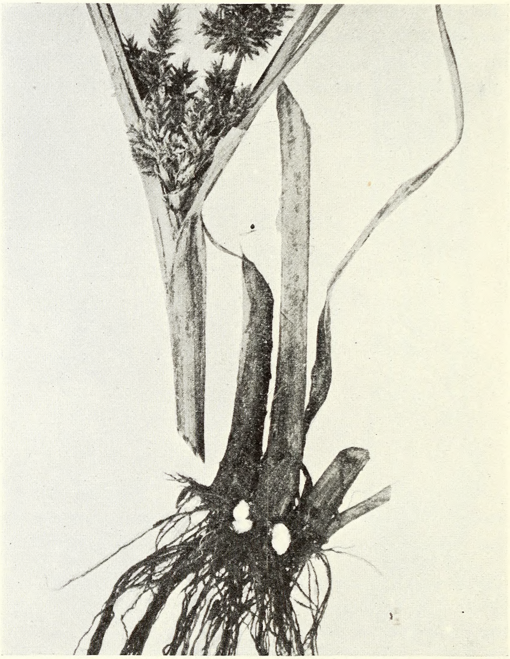


FIGURE 11. Southern Corn Bill Bug larvæ in crown of Red Rooted Cyperus Grass. X ½

LIFE HISTORY SUMMARY

The following summary is based largely upon observations made on the Pender Test Farm in the southeastern part of the State, but it is thought that the same conditions would be found practically throughout the area of greatest prevalence of the corn bill bug (Fig. 2). The adults hibernate over winter (Fig. 14), going into hibernation in late October (October 17th being the latest recorded date). They emerge

from hibernation in mid-April (April 10th being the earliest date recorded). Their numbers seem to increase rather rapidly until late May and after that rather slowly until mid-August. This increase is perhaps largely due to the fact that new adults are continually emerging from pupa whose larva have developed from eggs laid early in the spring. After mid-August the numbers of adults diminish rapidly, so that in early corn practically all the adults have disappeared by the end of August. A few adults remain active to late October. The adults commence to lay eggs by early May (May 5th being the earliest recorded date). The number of eggs found in the field increases rather rapidly until mid-June and then less rapidly until mid-July, the number of eggs falling off slightly toward mid-August. After which the number decreases rather rapidly. The latest date recorded

FIGURE 12. Cyperus Grass growing in a swamp to show characteristics.

for finding eggs in the field is September 23d, but as they were still rather common at that time, it seems safe to conclude that egg laying continues until early October, especially as the adults are active in the fields till late October. The distribution of the larvæ throughout the year seems to coincide rather closely with the distribution of the eggs. The earliest larvæ have been found in the field in mid-May, but the time of greatest abundance seems to be from late July to mid-August. After this time their numbers fall off rapidly, the latest larvæ being found in late October. (Larvæ in what appeared to be the fourth molt being found on October 27th.) The earliest pupæ have been found in late June. The number increases rather rapidly till late July and seems to remain nearly constant till late September; the latest pupa being found on November 9th. These late maturing pupæ seem to all change to adults before winter, and these adults seem to remain in the

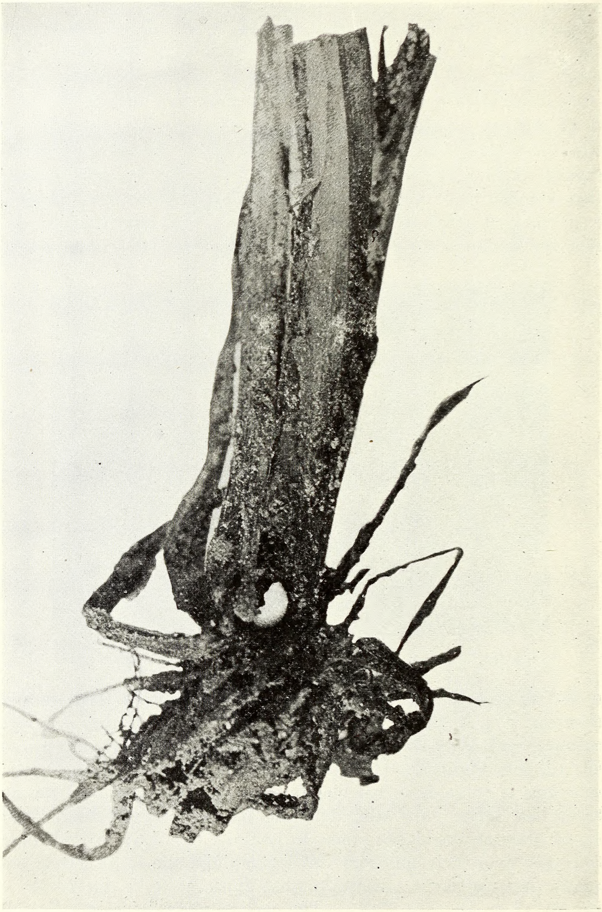


FIGURE 13. Larva feeding on the roots of Cyperus Grass.

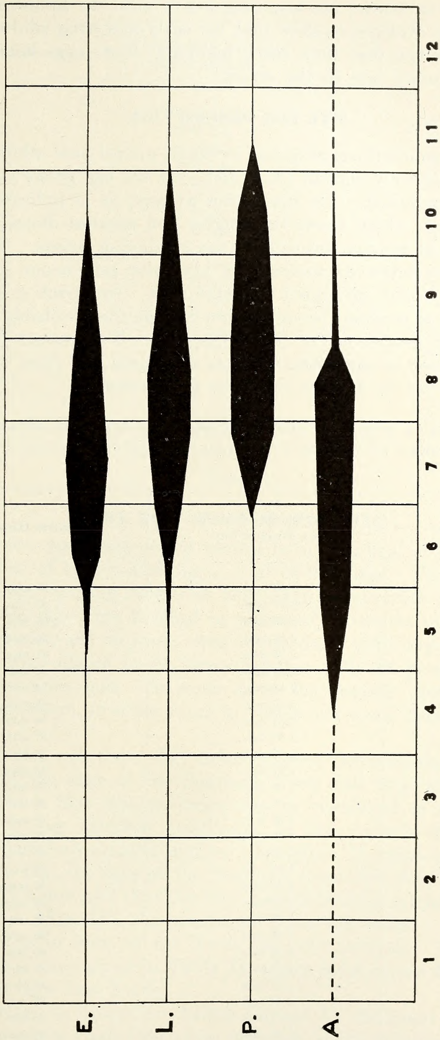


FIGURE 14. Life history summary. E. Eggs. L. Larvæ. P. Pupæ. A. Adults. The dotted line shows hibernation time. The figures at the bottom refer to the months.

pupal cells over winter, not becoming active until the following spring. There is some evidence to show that the early maturing adults lay eggs the same summer that they reach maturity, these eggs hatching and reaching maturity late in the season.

THE EGG DESCRIPTION

The egg is subreniform-elliptical in shape, almost pure white in color, and almost perfectly smooth (Fig. 15). As the egg grows older it becomes more yellowish. Its size varies greatly, as is indicated by the following table, which shows the lengths and greatest diameters of 51 eggs selected at random throughout the egg-laying season. The measurements were taken by means of a binocular microscope fitted with micrometer eyepiece calibrated to 0.0416 m.m. Inasmuch as these eggs were selected at random throughout the season, they probably represent fairly average conditions for North Carolina. No constant differences between the sizes of eggs taken early in the season and those taken later in the season can be detected from the measurements.

MEASUREMENTS OF 51 EGGS OF THE SOUTHERN CORN BILL BUG—MEASUREMENTS TAKEN AT VARIOUS TIMES THROUGHOUT THE SEASON.

TABLE I.

Egg Number	Total Length, Measured as a Straight Line	Greatest Diameter
1	2.08 mm.	.95 mm.
2	2.91 mm.	1.03 mm.
3	2.08 mm.	1.03 mm.
4	2.36 mm.	1.03 mm.
5	2.95 mm.	.91 mm.
6	2.91 mm.	.91 mm.
7	2.50 mm.	.95 mm.
8	2.41 mm.	.95 mm.
9	2.33 mm.	1.03 mm.
10	2.54 mm.	.91 mm.
11	2.37 mm.	.86 mm.
12	2.50 mm.	.86 mm.
13	2.08 mm.	.95 mm.
14	2.28 mm.	.83 mm.
15	2.33 mm.	.83 mm.
16	2.45 mm.	.86 mm.
17	2.28 mm.	.86 mm.
18	2.95 mm.	.86 mm.
19	2.28 mm.	.91 mm.
20	2.24 mm.	.86 mm.
21	2.37 mm.	.99 mm.
22	2.50 mm.	.95 mm.
23	2.50 mm.	.99 mm.
24	2.24 mm.	.91 mm.
25	1.95 mm.	.98 mm.
26	2.41 mm.	.98 mm.
27	2.17 mm.	.70 mm.
28	2.46 mm.	.96 mm.
29	2.02 mm.	.88 mm.

Egg Number	Total Length, Measured as a Straight Line	Greatest Diameter
30	2.15 mm.	.90 mm.
31	2.54 mm.	.96 mm.
32	2.10 mm.	.93 mm.
33	2.21 mm.	.91 mm.
34	2.12 mm.	.91 mm.
35	2.19 mm.	.89 mm.
36	2.12 mm.	.91 mm.
37	2.05 mm.	.93 mm.
38	2.21 mm.	.92 mm.
39	2.28 mm.	.88 mm.
40	2.10 mm.	.88 mm.
41	2.19 mm.	.91 mm.
42	2.31 mm.	.91 mm.
43	2.57 mm.	.93 mm.
44	2.29 mm.	.85 mm.
45	2.27 mm.	.95 mm.
46	2.41 mm.	.91 mm.
47	2.18 mm.	.89 mm.
48	2.29 mm.	.87 mm.
49	2.54 mm.	.93 mm.
50	2.39 mm.	1.04 mm.
51	2.42 mm.	.93 mm.

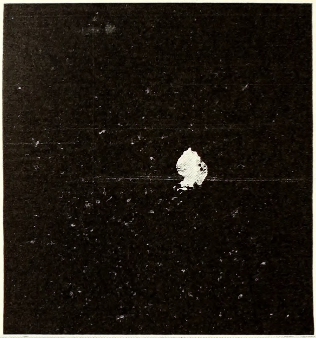
THE EGG. TIME OF HATCHING

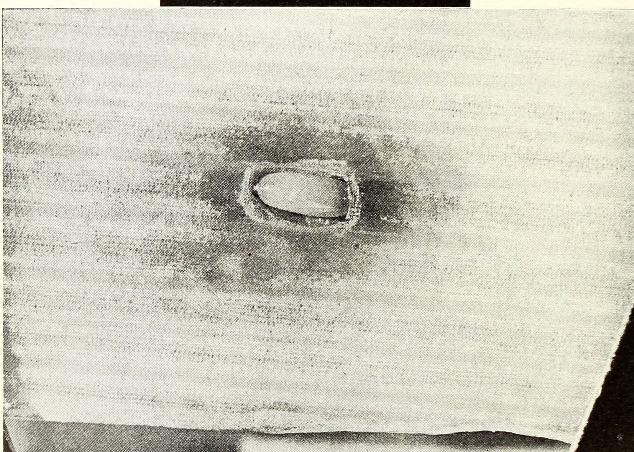
During the egg-laying period records have been kept of a total of 143 separate lots of eggs containing a total of 903 eggs. These eggs were hatched under varying conditions both as to temperature and moisture. Some of the eggs were hatched in pieces of cornstalks placed in vials or in tin boxes, and in some cases where there were large numbers of eggs they were placed in tin boxes together with the piece of corn on which they were laid. In some cases the records were secured to within four hours, in other cases to within not more than twenty-four hours.

These tables will show that there is great variation in the time of hatching of the eggs of the Southern Corn Bill Bug, and while the writer believes that this variation can be controlled to a very great extent by giving identical conditions, he also believes that no such uniform conditions exist in nature. Therefore, it seems perfectly safe to conclude that the eggs of the Southern Corn Bill Bug hatch in not less than 77 hours and that the time may be greatly extended certainly to 305 hours (Fig. 18), the mean time being 132 hours.

The figures in some of the tables are very accurate. This is especially true of the figures in Table II, where some of the figures are to within less than four hours.

In securing the figures for Tables III and IV the usual practice was to give the adults fresh food about 6 o'clock in the evening and then to remove this food about 8 o'clock in the morning. In most of the cases the eggs were examined about 8 o'clock in the morning, at noon, and





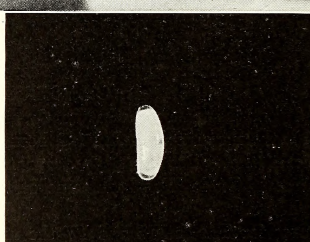


FIGURE 15. Egg of Southern Corn Bill Bug. X6. FIGURE 16. Egg of Southern Corn Bill Bug in natural position in pocket in outer leaf blade. X9.
FIGURE 17. Larva of Southern Corn Bill Bug. Just hatched. X6.

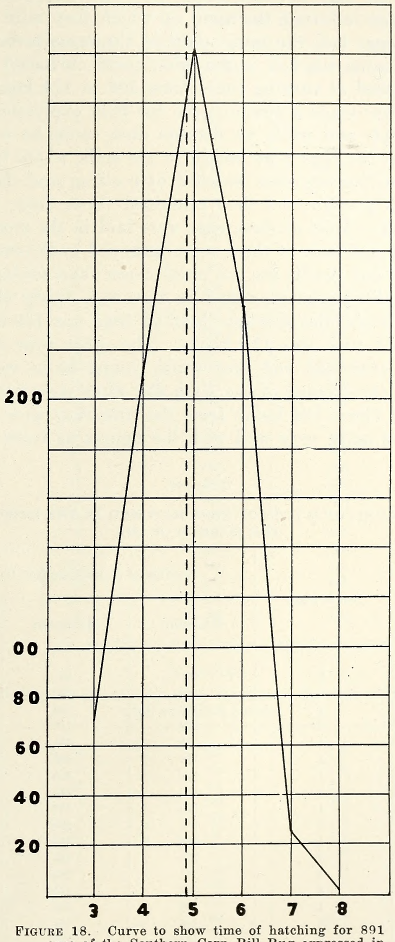


FIGURE 18. Curve to show time of hatching for 891 eggs of the Southern Corn Bill Bug expressed in one-day intervals. The mean time is shown by the dotted vertical line (........).

again in the evening. In most of the cases, as will be seen from the above figures, the eggs hatched about noon on the fourth, fifth, sixth, and seventh days following the night on which they were laid.

Frequently eggs laid the same night in the same piece of corn and stored in the same tin box under what must obviously be the same conditions hatched at varying times from 102 to 174 hours.

This point was made a special issue for field experiment during the summer of 1914, and while no definite data could be secured, owing to the fact that the eggs were buried in the stalk where they could not be observed, yet females were watched ovipositing and the egg marked as carefully as possible and then examined three, four, five, six, and seven days later. Most of these eggs were laid in the morning between 5 and 8 o'clock and most of them were examined in the evening between 4 and 6; hence our results are not much closer than twelve hours. But out of twenty-three eggs examined in this way, fairly close time was secured on only six, the shortest observed time was 130 hours and the longest recorded time was 177 hours. The other four eggs that had hatched when examined and near which young larvæ were discovered were found in the evening of the sixth day after they were laid, giving a total time of about 154 hours from the time they were laid.

These figures agree very well with the figures as from the following tables.

TABLE II.

INCUBATION RECORD OF 53 LOTS OF EGGS HATCHED IN THE INSECTARY DURING THE SUMMER OF 1911.

Lot No.	No. of Eggs	Number of Hours Required for Hatching		
		Minimum	Maximum	Average
1	6	151	161	156
2	1	150	160	155
3	2	156	160	158
4	4	168	178	173
5	1	174	184	179
6	1	188	195	192
7	1	193	205	199
8	2	170	183	177
9	1	170	183	177
10	1	158	169	164
11	1	150	166	158
12	5	123	147	135
13	5	141	165	153
14	4	127	151	139
15	1	186	192	189
16	26	148	164	156
17	5	139	143	141
18	1	305	329	317
19	4	137	141	139
20	3	161	165	163
21	1	141	142	142
22	3	161	163	162

Lot No.	No. of Eggs	Number of Hours Required for Hatching		
		Minimum	Maximum	Average
23	5	144	159	152
24	1	137	139	138
25	2	148	150	149
26	5	132	147	140
27	6	145	160	153
28	12	145	165	155
29	1	162	164	163
30	3	120	144	132
31	1	144	168	151
32	1	159	161	160
33	8	146	167	151
34	1	129	150	140
35	1	210	216	218
36	2	159	164	162
37	5	223	247	135
38	10	148	172	160
39	5	144	168	156
40	6	141	173	156
41	4	128	147	138
42	4	142	165	154
43	23	147	158	153
44	3	132	142	137
45	7	141	151	146
46	2	144	160	152
47	10	128	144	136
48	8	151	172	162
49	6	137	144	141
50	22	136	143	140
51	11	139	143	141
52	13	96	120	108
53	3	94	118	106

TABLE III

INCUBATION RECORD OF 25 LOTS OF EGGS HATCHED IN THE INSECTARY DURING THE SUMMER OF 1913.

1	4	103	115	109
2	5	124	136	130
3	11	102	114	108
4	5	108	120	114
5	5	84	96	90
6	15	103	115	109
7	4	77	89	83
8	6	84	96	90
9	6	102	118	108
10	6	78	90	84
11	8	109	121	115
12	17	85	97	91
13	7	109	121	115
14	10	80	92	86
15	4	85	97	91
16	3	102	114	108
17	4	132	144	138
18	13	133	145	139

Lot No.	No. of Eggs	Number of Hours Required for Hatching		
		Minimum	Maximum	Average
19	8	134	146	140
20	15	158	170	164
21	6	120	132	126
22	16	133	145	139
23	16	109	121	115
24	21	109	121	115
25	19	84	96	90

Table IV

INCUBATION RECORDS OF 65 LOTS OF EGGS HATCHED IN THE LABORATORY DURING THE SEASON OF 1915.

1	7	102	114	108
2	8	126	138	132
3	8	102	114	108
4	9	127	139	133
5	8	103	115	109
6	10	133	145	139
7	11	109	121	115
8	2	128	140	134
9	2	104	116	110
10	7	126	138	132
11	5	102	114	108
12	10	125	137	133
13	6	126	133	132
14	7	150	162	156
15	4	174	186	180
16	11	150	162	156
17	4	174	186	180
18	6	126	138	132
19	6	150	162	156
20	2	174	186	180
21	6	126	138	132
22	3	150	162	156
23	1	174	186	180
24	7	126	138	132
25	2	150	162	156
26	3	174	186	180
27	10	126	138	132
28	2	150	162	156
29	6	150	162	156
30	3	174	186	180
31	2	126	138	132
32	6	150	162	156
33	13	126	138	132
34	2	150	162	156
35	14	102	114	108
36	5	126	138	132
37	13	102	114	108
38	4	126	138	132
39	15	102	114	108
40	3	126	138	132
41	1	102	114	108
42	15	126	138	132

Lot No.	No. of Eggs	Number of Hours Required for Hatching		
		Minimum	Maximum	Average
43	6	102	114	108
44	6	126	138	132
45	3	102	114	108
46	4	126	138	132
47	2	102	114	108
48	8	126	138	132
49	1	102	114	108
50	11	126	138	132
51	12	126	138	132
52	10	126	138	132
53	5	126	138	132
54	5	150	162	156
55	8	150	162	156
56	5	126	138	132
57	4	150	162	156
58	7	150	162	156
59	8	102	114	108
60	3	126	138	132
61	7	102	114	108
62	4	126	138	132
63	6	126	138	132
64	3	150	162	156
65	2	126	138	132

WHERE LAID

Practically all of the eggs laid in the field are placed in the base of the cornstalk below the surface of the ground, or within an inch above the surface of the ground. In the cyperus plant the female seems to have a tendency to lay the eggs higher up. In young corn the eggs are usually laid deep in the heart of the stalk in especially prepared cavities (Fig. 8), but in older stalks the eggs are more frequently laid in the sheath of the outer blade, in a little pocket (Fig. 16).

Frequently in the field the eggs are loosely placed below the surface of the ground among the roots. In all cases where females had been watched closely they seemed to have a tendency to lay the last egg carelessly. In several cases where females had been observed to deposit one egg with the greatest care, the second egg was deposited in only a very shallow cavity or loosely among the roots. These females gave every evidence of being tired of the process of oviposition, and seemed to abandon all their usual precautions in egg laying.

Frequently, also, in our breeding cages loose eggs would be deposited. This tendency seemed to be greater when a layer of sand was placed in the breeding cages. So far as observed, these eggs seemed to be as fertile as eggs more carefully deposited. In no case where the female

deposited only a single egg was this egg deposited loosely, but always, so far as the writer's observations go, such eggs were deposited with the greatest care.

NUMBER LAID

The number of eggs laid by single females was the subject of a detailed experiment by Mr. Smith. The total number of eggs laid each day by 35 pairs as recorded by him is reproduced below in Table V. These records run from May 24th to September 29th. The daily egg-laying record of 23 pairs as recorded by the writer during the summer of 1914 is appended as Table VII. These records run from June 16th to August 24th.

In securing these records, single pairs were isolated in small jelly glasses and provided with a short section of cornstalk. These sections of cornstalk were cut from fresh stalks secured from the field every day, the sections being cut from the base of the stalk near the ground. In as far as possible, an attempt was made to secure food comparable to that found in the field. Towards the end of the season these stalks became hard and unsatisfactory for food, but they were always comparable to stalks found in the field.

In the field our records show that egg laying commences in early May, May 5th being the earliest date recorded at Willard. Egg laying continues through the season until September 21st in the field. But after August 15th the number of eggs diminishes very rapidly, owing perhaps to the fact that suitable corn cannot usually be found after that date. There is some evidence that the adults emigrate to cyperus from the cornfields late in the season, but the writer has never found eggs on cyperus after the middle of August. From these records it would seem that egg laying in the field actually surpasses our longest insectary record. This is perhaps due to the fact that insects brought from the eastern part of the State are set back in their egg laying, due, perhaps, to differences of temperature and moisture, and perhaps due to unnatural conditions during transportation. In part, the larger field record might be due to young adults which emerge in midsummer and lay a few eggs, but the fact that some of the adults in the insectary laid eggs as late as the 29th of September, at least a week later than eggs have been found in the field, would tend to minimize this factor.

According to our records, the greatest number of eggs laid in any single day was 11, and records of 5 to 10 are fairly common. The greatest number of eggs laid by any female, so far as observed, in the field, under perfectly natural conditions, was three eggs between 4:30 a. m. and 9:15 a. m. and then again in the evening between 6:30 and 7 she laid a single egg. In all, during the season of 1912 470 individuals were marked and observed for their egg-laying habits. None of these females were observed to lay eggs every day, but they were observed to lay often enough to lead one to conclude that they did lay

every day. Many individuals were observed to lay a single egg, and in one case one female was observed to lay an egg each day for three days in succession. Other individuals were observed to lay eggs on many separate occasions. Four individuals were observed to lay two eggs in the same day, these individuals being under almost continuous observation from 3:30 a. m. to 11 p. m.

From these observations it would seem safe to conclude that our daily egg records taken in the insectary would not be far from the conditions as they exist in the field; that is, that each female normally lays from one to at least four and perhaps more eggs each day from early May to late August, and perhaps more or less regularly from late August to late September.

TABLE V

EGG LAYING RECORDS

1911		Pair Number 1	2	3	4	5	6	7	8	9	10	11	12
May	24		4										
	25		1										
	26		1										
	27		1										
	28	3	3	0	5	0	2	5	5	1	1	5	5
	29	2	0	4	1	5	4	2	3	1	4	2	1
	30	2	2	0	1	1	1	3	2	0	1	0	4
	31	4	3	1	3	4	4	4	3	2	1	0	3
June	1	3	3	3	2	5	3	4	3	0	1	1	4
	2	4	4	3	4	7	3	4	4	1	1	4	4
	3	4	4	1	0	3	4	3	2	3	3	3	5
	4	1	4	4	3	6	6	3	5	0	3	4	3
	5	1	0	2	0	4	4	1	3	2	1	2	6
	6	3	5	5	0	6	3	3	1	0	4	7	5
	7	2	3	1	1	6	5	4	3	1	3	4	3
	8	1	3	2	0	3	4	1	2	0	0	4	5
	9	2	2	0	0	4	4	2	3	0	3	3	3
	10	1	3	3	0	3	3	1	0	2	4	3	6
	11	2	2	1	1	4	3	3	3	0	2	2	4
	12	4	3	3	1	9	3	2	2	2	5	5	6
	13	3	3	0	1	3	1	1	2	2	2	5	3
	14	3	4	3	3	6	0	1	1	1	0	3	7
	15	2	3	3	0	4	5	4	1	0	2	4	2
	16	1	4	4	2	7	6	0	2	1	4	5	8
	17	4	1	2	2	3	2	5	2	1	4	2	7
	18	2	3	2	0	4	4	1	2	1	1	6	1
	19	4	2	4	3	4	6	4	3	3	4	4	4
	20	2	3	2	0	5	5	0	2	2	3	5	4
	21	2	2	3	2	6	5	3	2	3	4	4	5
	22	2	4	2	1	5	3	1	2	2	2	2	4
	23	2	5	3	2	3	4	3	1	3	4	5	8
	24	3	3	4	2	5	7	2	4	3	4	5	1
	25	3	4	3	1	8	3	2	3	1	2	4	6
	26	4	4	4	2	6	7	2	3	2	3	6	5
	27	4	5	3	0	3	8	1	1	0	1	6	9
	28	2	6	3	3	6	5	0	4	3	1	3	4
	29	3	6	5	0	4	4	0	3	2	0	6	6
	30	2	4	5	1	2	6	2	2	3	0	5	2
July	1	2	4	6	2	4	5	0	3	2	0	2	4
	2	0	5	3	1	2	7	0	2	4	0	3	11
	3	1	5	6	0	3	5	2	1	2	0	6	5
	4	1	4	4	0	4	5	0	5	2	0	4	4
	5	0	3	2	1	4	3	1	4	2	0	4	6
	6	0	6	4	1	4	5	0	3	4	0	4	4
	7	1	3	2	0	3	3	1	3	1	0	7	8
	8	1	7	3	0	5	2	0	5	3	0	3	5
	9	2	5	3	0	4	5	0	2	3	0	5	5
	10	3	4	3	0	3	3	2	4	3	0	4	4
	11	1	6	3	0	1	8	0	2	1	0	3	4
	12	0	5	4	0	4	5	1	4	3	0	4	9
	13	2	6	1	0	5	1	1	4	3	0	4	9
	14	3	5	2	0	4	5	0	2	3	0	4	4
	15	3	3	2	0	2	3	0	2	2	0	5	5
	16	0	5	3	0	4	5	1	4	5	0	3	7
	17	0	5	3	0	6	4	0	3	3	0	6	6

TABLE V.

FOR 35 PAIRS, SUMMER 1911.

Pair Number

13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----
----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2	----	----
----	----	----	0	----	1	----	----	----	----	----	1	----	----	0	2	----	----	----	----	0	----	----
----	----	----	0	----	1	----	----	----	----	----	0	----	3	2	1	----	----	----	----	1	----	----
4	2	0	1	4	0	5	2	4	1	4	0	1	2	0	0	2	0	0	5	0	0	0
0	3	0	1	3	1	2	1	2	3	2	1	1	2	0	1	3	0	0	3	0	3	0
2	1	0	0	4	5	2	0	0	0	1	2	3	2	0	1	0	0	0	0	0	0	0
0	2	9	2	4	0	3	2	7	3	3	0	2	2	1	1	0	6	0	1	0	3	0
3	2	4	1	4	2	4	2	3	1	2	1	1	2	0	3	2	0	3	2	0	0	0
1	3	3	2	2	6	3	2	9	2	4	3	1	2	0	0	0	0	0	4	0	0	0
2	1	3	0	3	2	3	1	4	1	1	1	0	2	0	1	0	2	0	2	0	0	1
2	0	1	1	2	2	2	2	4	3	3	1	2	1	0	0	0	1	1	3	0	1	0
1	1	4	1	5	1	1	0	1	3	5	0	1	2	0	1	0	0	0	1	0	1	0
3	2	5	1	2	5	4	0	8	2	1	1	0	3	0	0	1	0	2	1	0	0	0
1	2	2	4	2	1	0	1	4	2	1	0	0	0	0	1	0	0	0	0	0	0	1
0	0	2	1	1	3	3	2	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0
0	2	4	1	1	0	0	0	4	2	1	0	0	0	0	0	0	0	0	0	0	0	0
2	2	4	1	0	5	3	1	6	3	1	0	0	0	0	0	0	1	0	0	0	0	0
0	1	2	0	1	1	1	0	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0
2	5	6	1	2	3	2	2	3	3	1	1	1	0	0	0	0	0	0	0	0	0	0
1	3	5	1	2	3	3	1	1	3	2	1	0	0	0	0	1	0	0	1	0	0	0
0	0	6	4	1	2	1	1	6	4	3	0	0	0	0	0	0	0	0	1	0	0	0
1	1	4	1	0	2	1	0	1	2	3	0	0	0	0	0	0	0	0	0	0	0	1
1	6	8	2	2	3	0	2	4	4	2	0	0	0	0	0	0	0	0	0	0	0	0
0	2	7	0	1	5	0	0	5	3	3	0	0	0	0	0	0	0	0	0	0	0	1
0	0	2	1	1	2	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	4	7	0	1	5	0	0	3	3	2	1	0	0	1	0	0	0	0	0	0	0	0
0	2	6	2	0	2	1	1	4	0	3	1	0	0	0	0	0	0	0	0	0	0	0
1	1	4	0	2	3	0	2	4	6	1	0	0	0	0	0	0	0	0	0	0	0	0
2	3	5	0	0	4	1	0	3	2	3	0	0	0	0	0	0	0	2	0	0	0	0
2	1	5	0	2	4	0	0	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	10	0	1	4	0	0	1	4	4	0	0	0	0	0	0	0	0	0	0	0	0
1	3	5	0	4	2	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2	4	9	0	3	5	0	0	3	4	1	0	0	0	0	0	0	0	0	0	0	0	0
1	3	7	0	0	5	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	5	0	3	2	0	0	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0
0	3	7	0	0	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	6	0	2	4	2	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	6	0	0	3	0	0	4	5	1	1	0	0	0	0	0	0	0	0	0	0	0
0	2	5	0	0	3	0	0	2	4	2	0	0	0	0	0	0	0	0	0	0	0	0
0	3	4	0	1	2	0	0	3	4	2	0	0	0	0	5	0	0	4	0	0	0	4
1	2	4	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	2	7	0	0	2	0	0	4	5	1	0	0	0	1	0	0	0	0	0	0	0	0
0	5	5	0	1	1	1	0	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0
0	4	0	0	0	0	0	0	3	4	1	0	0	0	0	0	0	0	0	0	0	0	0
0	4	4	D	0	2	0	0	2	8	0	0	0	0	0	0	0	0	0	0	0	0	0
0	4	2	----	0	1	0	0	3	4	3	2	0	0	0	0	0	0	0	0	0	0	0
0	3	6	----	1	1	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0
0	5	3	----	0	0	3	0	5	6	2	0	0	0	0	0	0	0	0	0	0	0	0
0	5	7	----	0	0	4	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
0	3	6	----	0	1	4	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
0	4	6	----	0	0	5	0	2	5	1	1	0	0	0	0	0	0	0	0	0	0	0
0	4	3	----	0	0	5	0	2	5	2	0	0	0	0	0	0	0	0	0	0	0	0
0	3	3	----	0	0	6	0	3	5	2	0	0	0	0	0	0	0	0	0	0	0	0
0	2	3	----	2	1	4	0	3	4	1	1	0	0	0	0	0	0	0	0	0	0	0

1911		Pair Number											
		1	2	3	4	5	6	7	8	9	10	11	12
July	18	1	7	4	0	3	3	0	6	4	0	4	6
	19	1	5	6	0	3	4	1	4	3	0	3	5
	20	0	2	7	0	2	7	0	4	3	0	1	3
	21	1	7	5	1	5	5	1	3	5	0	5	8
	22	0	4	8	0	2	7	2	2	4	0	6	2
	23	0	3	4	0	5	4	1	3	4	0	4	5
	24	1	6	5	0	3	2	1	5	5	0	6	4
	25	1	7	10	0	5	10	2	2	5	0	4	7
	26	0	1	3	0	1	3	1	1	3	0	5	2
	27-28	1	7	9	0	5	6	2	5	6	0	9	6
	29	0	7	7	0	4	5	2	2	3	0	5	1
	30	1	6	3	0	3	7	3	3	5	0	5	6
	31	1	3	4	0	3	2	3	3		0	3	3
August	1	1	8	6	0	6	8	1	0	5	0	6	2
	2	1	3	2	0	3	4	2	2	2	0	3	3
	3	1	5	4	0	3	1	0	2	4	0	7	0
	4	1	5	7	0	4	5	1	0	4	0	6	0
	5	0	6	3	0	3	4	1	2	2	0	4	0
	6	2	4	7	0	5	4	1	0	6	0	6	0
	7	0	4	7	0	4	4	0	0	2	0	8	0
	8-9-10	0	11	9	0	5	10	0	0	11	0	12	2
	11	0	4	6	0	1	4	0	0	3	0	6	0
	12	0	5	6	0	1	4	0	0	2	0	4	0
	13-14-15	0	13	8	0	5	11	0	0	4	0	10	2
	16	0	5	2	0	0	0	0	0	4	0	2	------
	17	0	2	1	0	0	2	0	0	1	0	0	------
	18	0	8	3	0	1	3	0	0	5	0	3	------
	19	0	3	3	0	4	6	0	0	4	0	4	------
	20	0	5	3	0	1	3	0	0	3	0	4	------
	21	0	0	0	0	0	0	0	0	0	0	0	------
	22	0	10	2	0	4	6	0	0	5	0	5	------
	23	0	0	0	0	0	0	0	0	0	0	0	------
	24	0	4	4	0	1	4	0	0	1	0	5	------
	25-26	0	5	0	0	0	7	0	0	1	0	7	------
	27	0	4	0	0	2	2	0	0	3	0	6	------
	28	0	4	0	0	1	2	0	0	4	0	2	------
	29	0	4	0	0	1	5	0	0	4	0	6	------
	30	0	5	0	0	2	5	0	0	3	0	2	------
	31	0	5	0	0	0	4	0	0	3	0	1	------
September	1-2	0	7	1	0	4	5	0	0	5	0	6	------
	3-4	0	7	7	0	3	4	0	0	6	0	6	------
	5	0	2	2	0	0	1	0	0	1	0	3	------
	6	0	5	0	0	0	5	0	0	2	0	0	------
	7	0	2	0	0	0	0	0	0	4	0	0	------
	8	0	3	0	0	0	1	0	0	2	0	0	------
	9	0	5	0	0	0	1	0	0	1	0	4	------
	10-11	0	7	0	0	1	3	0	0	1	0	2	------
	12	0	4	0	0	0	0	0	0	0	0	2	------
	13	0	1	0	0	1	0	0	0	0	0	4	------
	14	0	0	0	0	0	1	0	0	0	0	1	------
	15	0	1	0	0	0	1	0	0	0	0	0	------
	16	0	2	3	0	1	2	0	0	0	0	0	------
	17	0	0	0	0	0	0	0	0	0	0	0	------
	18	0	3	0	0	0	1	0	0	0	0	0	------
	19	0	1	0	0	0	1	0	0	0	0	1	------

Pair Number

13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1	3	8	----	1	0	5	0	4	3	1	2	0	0	0	0	0	0	0	0	0	0	0
0	4	3	----	0	0	6	0	3	4	3	0	0	0	5	4	0	0	0	0	0	0	0
0	2	4	----	0	0	4	0	2	3	2	2	Dis.	Dis.	Dis.	Dis.	Dis.	Dis.	Dis.	Dis.	Dis.	Dis.	Dis.
0	5	4	----	0	0	4	0	3	7	1	1	----	----	----	----	----	----	----	----	----	----	----
0	4	1	----	1	1	5	0	3	4	1	1	----	----	----	----	----	----	----	----	----	----	----
0	3	3	----	0	0	5	0	2	7	1	1	----	----	----	----	----	----	----	----	----	----	----
0	5	1	----	0	0	4	0	2	5	1	0	----	----	----	----	----	----	----	----	----	----	----
0	5	5	----	0	1	6	0	2	6	1	0	----	----	----	----	----	----	----	----	----	----	----
0	2	0	----	0	0	1	0	4	1	1	1	----	----	----	----	----	----	----	----	----	----	----
0	8	5	----	1	1	3	0	3	7	2	1	----	----	----	----	----	----	----	----	----	----	----
0	2	6	----	0	1	1	0	3	3	2	0	----	----	----	----	----	----	----	----	----	----	----
1	3	0	----	0	0	2	0	4	4	0	2	----	----	----	----	----	----	----	----	----	----	----
0	5	2	----	0	0	2	0	2	4	4	0	----	----	----	----	----	----	----	----	----	----	----
0	1	4	----	0	0	2	0	5	3	1	0	----	----	----	----	----	----	----	----	----	----	----
1	5	0	----	0	0	1	0	3	3	3	1	----	----	----	----	----	----	----	----	----	----	----
1	4	0	----	0	0	3	0	5	8	4	0	----	----	----	----	----	----	----	----	----	----	----
0	2	2	----	0	0	3	0	2	3	3	0	----	----	----	----	----	----	----	----	----	----	----
2	0	2	----	0	0	4	0	4	6	2	1	----	----	----	----	----	----	----	----	----	----	----
0	0	2	----	0	0	3	0	4	4	3	0	----	----	----	----	----	----	----	----	----	----	----
0	5	7	----	0	0	4	0	4	4	3	0	----	----	----	----	----	----	----	----	----	----	----
4	0	0	----	0	0	3	0	7	10	4	0	----	----	----	----	----	----	----	----	----	----	----
1	4	1	----	0	0	4	0	4	3	0	0	----	----	----	----	----	----	----	----	----	----	----
2	0	0	----	0	0	1	0	3	4	4	0	----	----	----	----	----	----	----	----	----	----	----
2	6	0	----	0	0	1	0	6	11	4	1	----	----	----	----	----	----	----	----	----	----	----
0	0	0	----	0	0	4	0	4	5	1	0	----	----	----	----	----	----	----	----	----	----	----
1	0	1	----	0	0	0	0	2	3	1	0	----	----	----	----	----	----	----	----	----	----	----
2	0	D	----	0	0	0	0	1	4	3	0	----	----	----	----	----	----	----	----	----	----	----
1	1	----	----	0	0	3	0	6	7	2	0	----	----	----	----	----	----	----	----	----	----	----
0	1	----	----	0	0	1	0	5	3	2	0	----	----	----	----	----	----	----	----	----	----	----
0	----	----	----	0	0	0	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
2	3	----	----	0	0	0	0	4	6	6	3	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	2	0	3	3	3	0	----	----	----	----	----	----	----	----	----	----	----
1	3	----	----	0	0	0	0	4	3	2	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	4	3	4	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	1	3	5	1	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	4	1	3	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	2	5	2	0	----	----	----	----	----	----	----	----	----	----	----
1	0	----	----	0	0	0	0	3	3	2	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	2	3	5	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	3	6	5	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	0	0	1	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	1	1	1	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	0	3	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	1	2	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	0	2	2	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	0	2	4	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	0	2	2	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	0	0	0	0	2	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	K	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	0	0	1	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	0	0	1	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	0	0	1	0	----	----	----	----	----	----	----	----	----	----	----

1911	Pair Number											
	1	2	3	4	5	6	7	8	9	10	11	12
September 20	0	1	0	0	1	1	0	0	1	0	1	------
21	0	0	0	0	D	0	0	0	0	0	0	------
22	0	0	0	0	------	0	0	0	0	0	0	------
23	0	0	0	0	------	0	0	0	0	0	0	------
24	0	0	0	0	------	0	0	0	0	0	0	------
25	0	0	0	0	------	0	0	0	0	0	0	------
26-27	0	1	1	0	------	1	0	0	0	0	0	------
28-29	0	0	0	0	------	1	0	0	0	0	0	------
Totals	121	447	314	53	328	413	111	185	256	78	409	320

Pair Number

13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
0	0	----	----	0	0	----	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	1	0	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
0	0	----	----	0	0	----	0	0	0	0	0	----	----	----	----	----	----	----	----	----	----	----
65	212	292	30	73	120	166	27	296	343	196	39	13	23	10	21	9	10	12	24	4	8	8

TABLE VI.

SUMMARY OF EGG LAYING RECORDS, BY MONTHS FROM TABLE V.

Pair Number	May	June	July	August	September	Totals
1	11	76	28	6	0	121
2	15	102	146	132	52	447
3	5	83	129	83	14	314
4	10	37	6	0	0	53
5	10	144	106	57	11	328
6	11	126	139	108	29	413
7	14	63	28	6	0	111
8	13	71	95	6	0	185
9	4	44	99	86	23	256
10	7	71	0	0	0	78
11	7	122	131	119	30	409
12	13	140	158	9	0	320
13	6	34	4	21	0	65
14	8	60	109	35	0	212
15	9	148	116	19	0	292
16	5	25	0	0	0	30
17	15	50	8	0	0	73
18	8	90	22	0	0	120
19	12	35	80	39	0	166
20	5	20	2	0	0	27
21	13	102	83	90	8	296
22	7	79	128	108	21	343
23	10	53	41	67	25	196
24	4	12	16	7	0	39
25	7	6	0	0	0	13
26	11	12	0	0	0	23
27	3	1	6	0	0	10
28	6	6	9	0	0	21
29	5	4	0	0	0	9
30	6	4	0	0	0	10
31	0	8	4	0	0	12
32	9	15	0	0	0	24
33	4	0	0	0	0	4
34	6	2	0	0	0	8
35	0	4	4	0	0	8
Totals.....	279	1,849	1,697	998	213	5,036

TABLE VII.

PAIRS NUMBERS 1 TO 23. COLLECTED ON PENDER

Eggs Laid		1	2	3	4	5	6	7
June	16	3	3	2	4	0	0	3
	17	2	4	2	0	0	0	1
	18	2	2	2	2	0	0	5
	19	0	1	1	1	0	0	4
	20	1	0	2	2	0	0	6
	21	2	2	2	1	1	0	6
	22	1	2	1	3	0	1	3
	23	2	2	2	1	0	0	1
	24	0	1	0	1	0	1	4
	25	2	4	0	2	0	1	10
	26	1	3	0	2	0	0	3
	27	1	5	0	7	1	0	2
	28	0	2	0	1	0	0	1
	29	3	3	0	2	0	1	5
	30	2	0	0	2	1	1	5
July	1	0	1	0	1	0	0	3
	2	0	0	0	1	0	0	1
	3	0	1	0	0	0	0	3
	4	2	3	0	8	0	0	9
	5	1	3	0	3	1	5	1
	6	0	2	2	0	0	1	0
	7	2	4	0	5	0	4	1
	8	3	2	1	4	1	5	8
	9	3	3	1	0	0	1	3
	10	1	1	0	5	0	1	8
	11	1	2	2	2	1	0	4
	12	3	2	0	4	0	7	11
	13	0	1	2	0	0	2	4
	14	4	1	2	3	0	2	7
	15	3	1	2	9	0	7	3
	16	4	3	3	7	0	2	4
	17	2	2	1	9	0	1	4
	18	3	0	6	5	0	3	7
	19	3	4	9	4	1	1	4
	20	1	1	0	0	0	2	0
	21	5	2	5	1	0	2	4
	22	4	5	7	6	0	3	5
	23	5	3	3	7	0	5	5
	24	8	3	6	11	0	0	7
	25-26	2	4	6	5	1	3	4
	27	4	3	5	5	1	3	2
	28	4	3	8	6	0	0	1
	29	4	0	5	4	0	3	1
	30-31	7	2	3	8	0	1	4
August	1	3	1	4	3	0	1	5
	2-3	5	*	6	8	1	0	4
	4	5	2	5	4	1	3	4
	5	6	1	3	6	1	5	4
	6	2	2	4	3	0	3	1
	7	5	2	3	6	0	3	5
	8	4	2	4	7	1	2	4
	9-10	7	4	6	1	1	0	1
	11-12	3	3	4	5	0	2	6
	13	3	2	0	9	1	7	2
	14-15	8	1	0	2	2	1	2

*Ants.

TABLE VII.

TEST FARM, JUNE 13, 1914—ISOLATED JUNE 15, 1914.

8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
5	4	0	0	2	0	7	0	0	2	0	2	5	2	7	3
2	1	0	0	2	1	3	6	0	1	0	1	4	1	2	8
2	4	0	1	3	2	2	0	0	0	0	1	6	1	6	2
1	1	0	6	3	1	2	3	1	3	0	2	4	0	2	4
1	1	0	0	0	0	2	0	0	2	0	2	4	0	1	2
0	3	0	0	0	3	1	3	0	0	0	2	1	3	2	4
2	1	0	2	3	2	2	1	0	1	0	1	4	0	5	1
3	0	0	0	1	3	3	1	0	0	2	2	5	0	5	2
2	1	0	1	4	1	0	1	0	0	0	2	1	0	1	2
1	0	0	0	2	4	4	0	0	3	0	1	5	0	2	0
0	0	0	0	5	4	2	3	0	0	1	1	5	0	7	4
0	0	0	2	12	12	2	8	0	0	0	1	4	0	2	2
2	0	0	2	3	3	3	1	0	1	2	0	7	0	3	4
0	1	0	1	5	4	2	3	0	0	0	2	4	0	†	4
1	0	0	3	0	2	0	1	0	0	8	1	1	0	5	3
0	0	0	3	1	5	0	1	0	0	0	2	4	0	3	2
0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0
0	0	0	2	1	0	0	0	0	0	0	0	0	0	3	0
1	0	0	6	4	3	1	4	0	0	0	0	5	0	7	3
1	0	0	7	2	0	0	1	0	0	3	1	3	0	1	2
0	1	0	1	2	1	0	0	0	0	0	2	0	1	2	2
0	0	0	3	4	3	0	3	0	0	0	0	3	1	3	4
1	2	4	7	5	3	0	1	0	0	0	1	4	0	4	2
2	1	3	4	5	4	1	3	0	2	4	1	5	3	6	4
5	0	2	4	3	1	1	1	0	0	0	0	3	1	6	4
2	0	2	2	2	3	2	2	0	0	4	3	8	3	3	3
3	1	4	3	4	5	1	6	0	0	2	2	3	4	5	2
3	0	4	2	2	1	2	2	0	1	1	2	1	0	2	2
2	0	6	1	6	2	2	4	0	0	†	†	†	5	5	6
2	0	7	6	7	3	1	1	1	0	0	2	4	5	6	1
3	3	4	4	3	6	1	1	0	0	0	0	0	2	6	4
1	8	3	2	3	4	0	0	0	1	0	0	0	1	2	0
3	5	8	1	4	4	3	1	0	0	0	0	4	3	5	2
2	6	5	6	3	1	2	1	0	2	0	1	4	4	4	1
0	1	3	0	4	1	0	0	0	0	0	0	0	0	0	0
2	4	2	2	2	2	3	0	0	0	0	0	0	2	5	5
2	7	6	0	2	2	4	0	0	1	0	0	1	5	1	4
4	4	6	5	9	5	4	0	0	1	0	0	2	2	3	1
4	9	5	5	1	1	3	0	0	1	0	4	1	2	0	5
1	0	7	5	4	6	3	0	0	3	1	1	5	0	4	4
1	7	4	2	3	3	0	0	0	1	0	2	0	1	1	------
0	4	2	0	5	3	7	0	0	5	0	1	1	1	2	2
0	3	5	3	0	4	3	0	1	5	0	3	1	2	4	3
1	12	9	2	2	0	13	0	1	8	0	0	8	3	0	2
0	3	3	5	8	3	4	0	1	3	0	3	1	2	5	4
0	9	7	1	2	3	1	0	3	4	0	0	3	2	2	1
0	9	7	2	3	0	4	0	1	0	0	3	4	3	3	7
0	3	4	1	3	2	3	0	1	0	0	2	0	4	2	3
0	5	5	3	5	3	2	0	2	0	0	3	0	2	4	3
0	4	5	3	4	5	5	0	2	6	0	0	6	4	2	3
3	4	4	6	5	3	2	0	1	1	0	1	3	0	4	2
1	2	10	3	1	5	9	0	1	3	1	0	9	7	5	3
1	4	11	2	9	2	5	0	2	5	0	0	5	7	4	2
5	7	7	9	4	3	2	0	1	5	0	0	5	6	7	2
0	0	4	7	0	4	1	0	1	0	0	0	2	3	2	2

†Without food.

Eggs Laid	1	2	3	4	5	6	7
August 18	10	3	3	3	1	0	9
20	0	0	3	1	5	3	2
24	0	1	0	0	0	3	0
Totals	162	120	137	211	23	102	229

8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2	4	2	3	10	2	0	1	0	0	0	1	2	0	0
0	8	1	1	2	4	0	0	2	0	0	0	5	1	0	0
0	9	0	1	1	4	0	0	0	0	0	0	0	5	0	4
79	164	173	153	188	169	132	64	23	71	43	61	174	106	179	151

Table VIII.

SUMMARY OF EGG LAYING RECORDS, BY MONTHS FROM TABLE VII.

Pair Number	June	July	August	Totals
1	22	79	61	162
2	34	62	24	120
3	14	78	45	137
4	31	122	58	211
5	3	6	14	23
6	5	64	33	102
7	59	121	49	229
8	22	46	11	79
9	17	78	69	164
10	0	101	72	173
11	18	89	46	153
12	45	93	50	188
13	42	76	51	169
14	35	57	40	132
15	31	33	0	64
16	1	3	19	23
17	13	31	27	71
18	13	15	15	43
19	21	28	12	61
20	60	70	44	174
21	7	51	48	106
22	50	89	40	179
23	45	70	36	151
Totals..........	588	1,462	864	2,914

WHEN THE EGGS ARE LAID

There are two main periods of oviposition during the day, just as there are two main periods of other activities. These two periods center around 8 o'clock in the morning and 6 o'clock in the evening. In a large field where the bill bugs are very prevalent adult females can be found laying eggs almost any hour of the day or night. But adults laying eggs are much more abundant at the periods mentioned and are comparatively rare or sometimes seemingly wanting from about 12 o'clock noon until 3 in the afternoon and again from about 12 o'clock midnight to 5 in the morning. A fuller discussion of the daily activities of bill bugs is to be found under the heading "Diurnal Activities" below.

HATCHING

As the young larvæ develop within the egg their form gradually becomes more and more evident until it is fully outlined. Then the egg-shell seems to split just as if the developing larva was too large for it. The larva may actually eat its way out, but close examination of many egg-shells failed to give any evidence that this was the case. One example was watched while hatching and the splitting of the egg-shell seemed to be due to the active wriggling of the larva. If

the egg-shell is actually eaten away by the larva, that fact could not be seen with the aid of a binocular microscope giving a magnification of 74 diameters.

Soon after hatching, the young larva commences to eat a tunnel downward and toward the center of the stalk.

PERCENTAGE OF EGGS HATCHING

During 1915, 37 different lots of eggs, making a total of 566 eggs, were watched in the insectary to determine the percentage of eggs that hatched. These eggs were placed in small tin boxes with sufficient green corn to give them plenty of moisture. Of the 566 eggs, 433 hatched, giving 76 per cent hatching. No reason can be assigned for the failure of the 24 per cent to hatch. All eggs that had not hatched by the end of nine days after laying were discarded and counted as not hatching, as they had usually molded by this time. No attempt has been made to compare this with conditions in the field, because no satisfactory method could be devised for watching the eggs under natural conditions.

TABLE IX.

36 LOTS OF EGGS OBSERVED IN THE INSECTARY DURING 1915 TO DETERMINE PERCENTAGE HATCHING.

Lot Number	Number of Eggs	Hatched	Not Hatched	Date Laid
1	24	15	9	June 13
2	20	17	3	14
3	22	18	4	15
4	23	13	10	16
5	19	9	10	17
6	19	15	4	18
7	22	17	5	20
8	16	15	1	21
9	14	14	0	22
10	17	10	7	23
11	16	12	4	24
12	12	12	0	25
13	13	9	4	26
14	14	8	6	27
15	19	15	4	28
16	21	19	2	29
17	17	17	0	30
18	21	18	3	July 1
19	19	16	3	2
20	13	12	1	3
21	14	7	7	4
22	13	10	3	5
23	15	12	3	6
24	15	12	3	7
25	13	10	3	8
26	11	10	1	9
27	9	8	1	10
28	14	9	5	11
29	11	7	4	12
30	14	11	3	13

Lot Number	Number of Eggs	Hatched	Not Hatched	Date Laid
31	27	21	6	July 14-15
32	9	7	2	16-17
33	13	11	2	18
34	10	6	4	19-20
35	11	9	2	21
36	6	2	4	22
Totals	566	433	133	

THE LARVA DESCRIPTION

The larva of the Southern Corn Bill Bug is a fleshy footless grub with a yellowish brown head, much larger posteriorly (Figs. 19-22). The different molts are practically identical, there being no important differences save size. Length from 2 to 11 mm., depending upon the molt; soiled white; head yellowish brown; trophi darker, almost black; body fusiform, strongly curved, swelling ventrally from the third to the fifth abdominal segments, then recurved and rounding to the anal extremity. Head large, hemispherically oblong, longer than broad; epicranial suture distinct, continuing as a shallow impressed sulcus on the frons: a faintly indicated undulating line either side of the epicranial suture starting on the vertex and ending on the frontal sutures; frontal sutures distinct sinuate; epicranium with eight hairs either side of the epicranial suture arranged as shown in Fig. 23; frons with four hairs either side of median line as shown in Fig. 23; four shorter hairs on the clypeal margin; antennæ rudimentary; clypeus free, transverse trapezoidal, sides converging ventrad; labrum smaller, semicircular, bearing a row of four long medial, four short submarginal, and eight shorter marginal hairs on the ventral curved margin, two prominent curving sulci either side of middle, dividing the labrum into three sub-equal halves; mandibles stout, triangular, with two short hairs near the base; maxillæ stout with three prominent hairs, cardo small, stipes large, elongate, bearing a short palpus with two unequal globular joints and a fleshy lobe thickly studded with hairs, which is concealed by the labium; labium consisting of a large triangular mentum with a median excavation on the distal part, palpiger triangular with a deep median groove, labial palpi equaling the maxillary palpi of two joints, ligula triangular rounded; three pairs of prominent hairs on the mentum, one pair on the palpiger and two pairs of short stout hairs on the outer surface of the ligula. Thoracic segments distinct; prothorax longer and broader with a chitenized shield on the dorsum, a large oblong spiracle middle of the sides of the prothorax. A pair of rather prominent hairs dorsally with two smaller ones between, nearer the median line and in front of these two pairs near the anterior border.

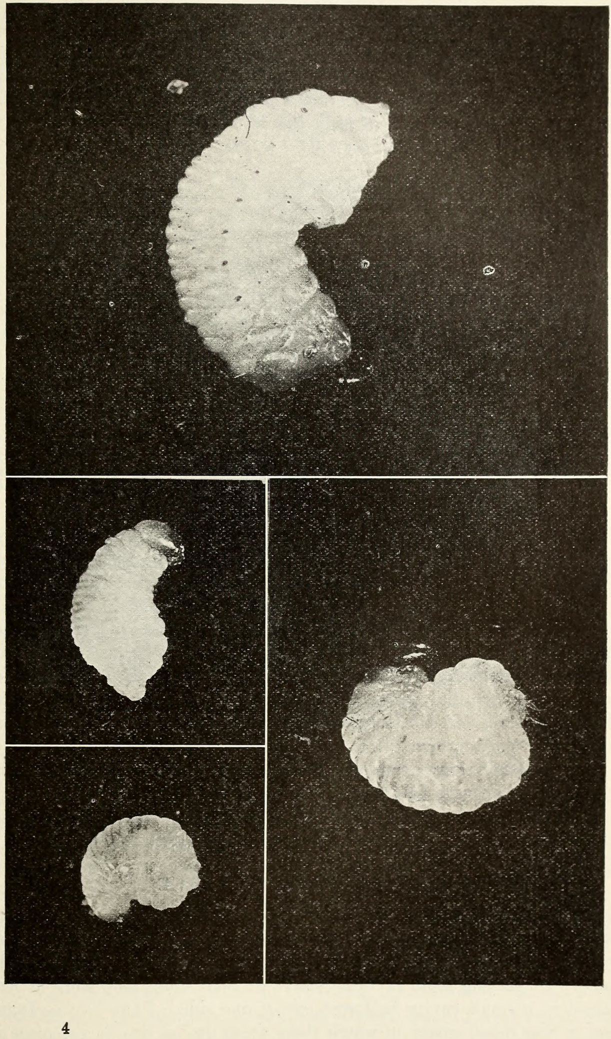


FIGURE 19. Larva just after first molt. X6.
FIGURE 20. Larva just after second molt. X6.

FIGURE 21. Larva just after third molt. X6.
FIGURE 22. Larva just after fourth molt. X6.

Posteriorly to the prominent pair there is a group of three hairs above the spiracle and four on the fleshy ventral protuberance. There is a pair each of the dorsal lobes of the mesothorax and metathorax. Three hairs on the dorso-lateral lobe of the mesothorax and two hairs on the metathorax. A single hair on each of the lateral lobes, ventro-lateral lobes, and the fleshy ventral protuberance of both the meso- and metathorax. The ventral lobes of each thoracic segment are provided with a median pair of hairs.

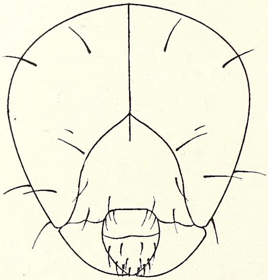


Figure 23. Frontal view of head of larva to show arrangement of hairs.

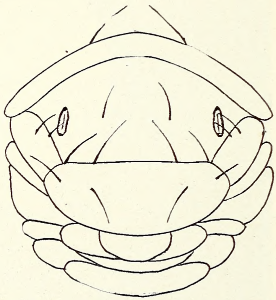


Figure 24. Seventh, eighth, and ninth abdominal segments of larva to show arrangement of hairs.

Abdominal segments forming on the dorsum a narrow transverse fold, separated by two wider folds; the eighth and ninth abdominal segments excavated above without dorsal folds; ventrally the first three segments contracted, the succeeding segments enlarged; laterally each segment has numerous longitudinal folds; abdominal spiracles smaller than prothoracic pair, eight pairs; the first seven pairs situated just above the lateral folds, the eighth pair situated in the excavation of the eighth abdominal segment; the eighth pair larger than the other abdominal spiracles, equaling the prothoracic pair; all with chitinous margins of dark brown color.

Each abdominal segment from one to seven has a pair of dorsal hairs, a single hair on each lateral and ventro-lateral lobe.

The arrangement of the hairs on the seventh, eighth, and ninth abdominal segments is quite characteristic, and is shown in Fig. 24.

METHODS OF REARING LARVÆ

Several different methods have been used for rearing larvæ in the course of this investigation. Practically all of our larvæ have been reared on the portion of the main stem of the corn plant just above the roots. In placing them in these pieces of corn stem, they were at first placed in a small cavity hollowed out of one side. Later it was found that it was much easier to watch them from day to day if the piece of

cornstalk was split lengthwise, a small hollow large enough to receive the larvæ made in one piece and the two bound together with rubber bands. In this way the larvæ could be observed as often as necessary without undue disturbance, as the larvæ could usually be found in the central cavity which had been prepared for them.

Part of the larvæ have been reared in an out-of-door insectary (Fig. 25), and part have been reared in the laboratory (Fig. 28).

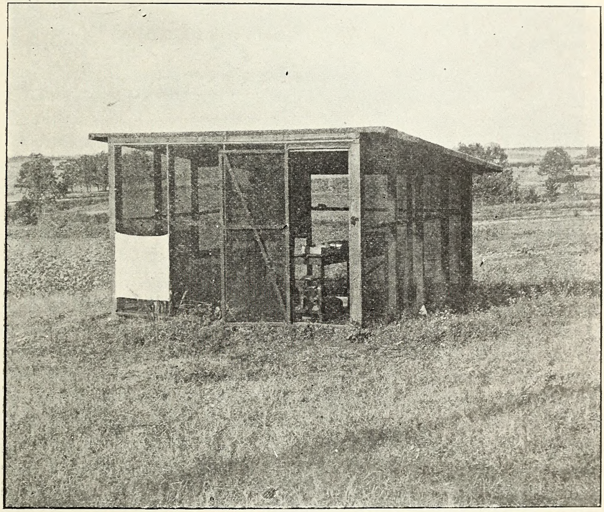


Figure 25. Insectary in which a part of the life history work on the Southern Corn Bill Bug was done. (After Smith.)

We have also reared larvæ in jelly glasses and in tin boxes, but of these two methods the tin boxes gave uniformly the better results and were much easier to handle. For this purpose we have used lately the Meyer's patent box, four-ounce size, which is provided with a permanent label on the lid (Fig. 27). This label was very convenient for making any records regarding the larvæ contained in the box, such as time and date of last observation, when last provided with food, date and time of molting, etc. Such records as were worthy of being permanently filed were put on sheets and filed in a vertical file. In this way there was no danger of confusing the record of one larva with another, and the complete record was always before the observer while examining any individual.

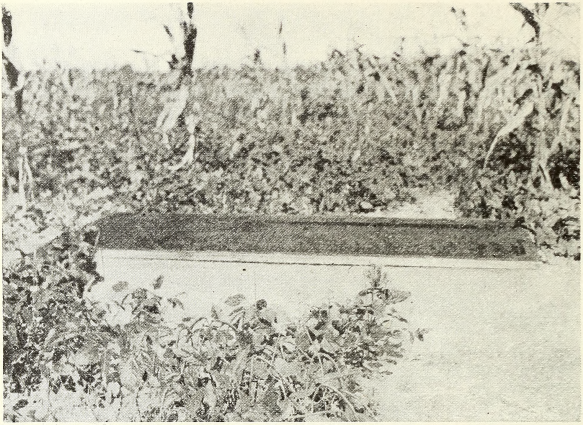


FIGURE 26. Hibernation cages used in the fields to determine the length of the hibernation period.

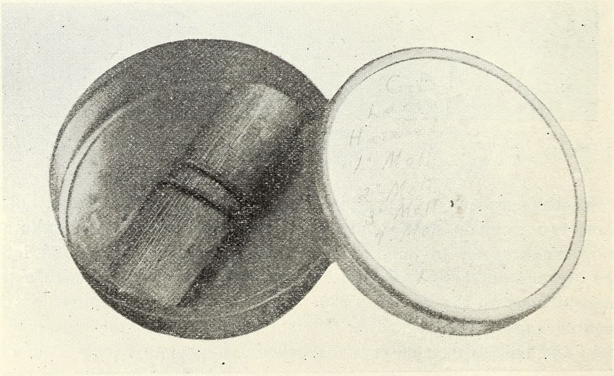


FIGURE 27. Tin salve box used in breeding the Southern Corn Bill Bug in the laboratory.

In the jelly glasses and in the tin boxes the pieces of cornstalk containing the larvæ were placed on and buried in damp soil, and placed on and buried in dry soil. Towards the end of the investigation all of these methods were discarded and the larvæ were kept in boxes without any soil. In this way there was no danger of losing the larva if it happened to abandon its piece of cornstalk.

By this method 192 larvæ have been reared from egg to adult and many other larvæ have been reared through part of their development.

Very careful records have been made of these larvæ; in many cases the exact hour when they hatched, or when they molted, has been recorded. For many cases, however, this has not been recorded; therefore, in the following records the time has been recorded only to the day. In most of this work two observations were made daily, one from about 8 to 10 a. m., the other from about 5 to 7 p. m. In this way the day was roughly divided into two periods approximating twelve hours each. Most of the changes, however, occurred at night and are recorded for the morning following the night on which they were made, and in a majority of cases, therefore, accurate to within twelve hours.

PROCESS OF MOLTING

The process of molting has been watched in several larvæ. Briefly, it may be described as follows: The larva first becomes somewhat stiff and loses its characteristic curved shape and becomes more or less straight (Fig 29). This usually precedes the actual molting an hour or two, but in some cases the larva commences to assume this attitude as much as eighteen hours before it actually molts. The older the larva the longer relatively this preliminary attitude seems to be. In the case of the last molt or change to the pupa it is frequently as long as two or three days (Fig. 30). While in this attitude the larvæ turns and twists about a great deal. This is especially marked as the mature larva prepares to pupate. In this way the inside of the pupal cell is smoothed and made compact, and this same result is noticed in the larval burrows, to a much less degree, however (Fig. 29).

The second step in molting is the splitting of the head. The old head gradually splits along the epicranial and frontal sutures, and gradually, as the larva turns and twists, the new head emerges and the old headpieces are worked posteriorly. The chiten covering the rest of the body is gradually worked backwards, and is left eventually in the burrow behind the larva. This chiten is very thin and evanescent and soon loses its identity, but the harder headpieces, particularly the mouth-parts, persist for a day or two. This whole process normally occupies about half an hour, but frequently the larva seems to become exhausted and to lie quietly for an hour or so before recommencing its interminable turning and twisting.

The head after molting is pure white, but in the course of an hour it commences to turn yellow and gradually it assumes the brownish

color characteristic of the larvæ between molts. This color is assumed very gradually, however, and frequently by close observation it is possible to distinguish a larva that has molted within the last twelve hours.

NUMBER OF MOLTS

In all, 221 larvæ have been raised from egg to pupal condition and many others have been carried through part of their development. Practically all of these larvæ evidently molted four times, but of this number only 93 were observed to make all their molts. A few indi-

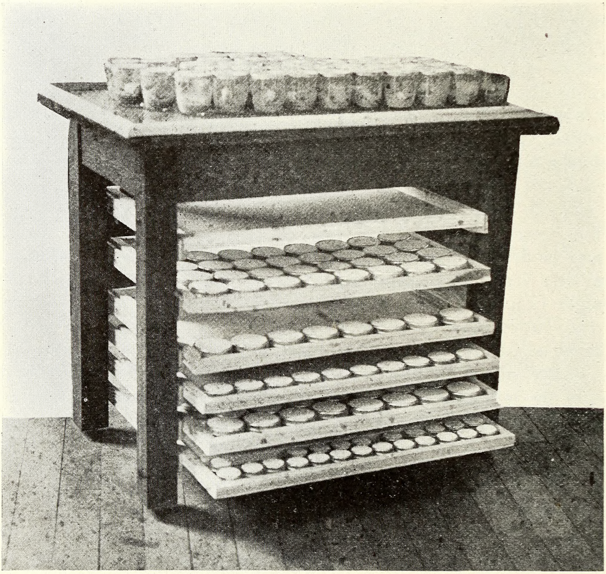


FIGURE 28. Laboratory table arranged with trays for holding jelly glasses and salve boxes used in breeding the Southern Corn Bill Bug.

viduals, fourteen in all, molted five times and three of these molted six times. From these observations it seems safe to conclude that the normal number of larval molts is four.

Observations made on the above fourteen larvæ would lead one to believe that poor food would increase the number of larval molts. In one case the larva was purposely given poor food after its fourth molt. It molted six times. In another case a larva was purposely given poor food from the time it hatched, and it molted six times. Several

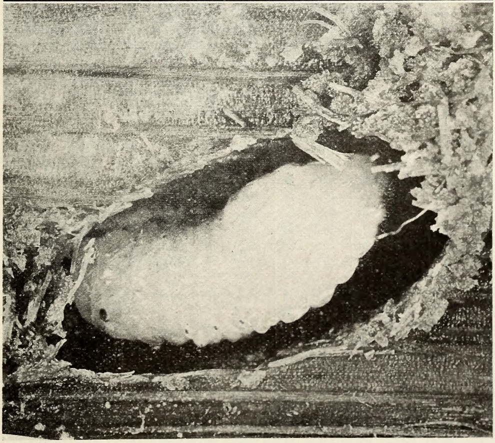


FIGURE 29. Larva preparing pupal cell. X6.

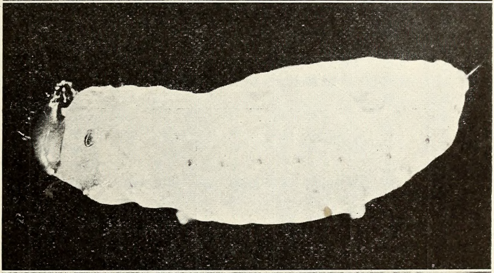


FIGURE 30. Larva just before fifth molt or pupation. X6

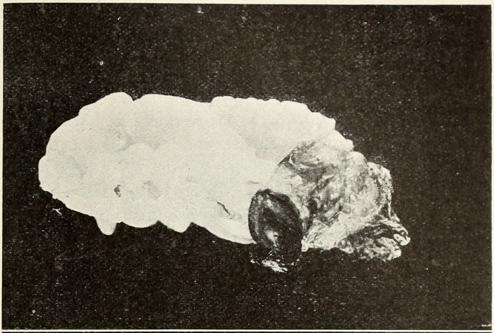


FIGURE 31. Pupa shedding larval skin. X6.

other individuals were tried in the same way, but we did not succeed in getting any more to pass through their stages, undoubtedly because the food was too poor.

In all our tables four has been taken as the normal number of larval molts, and all our calculations are based on these results. Whether the unnatural conditions of the insectary could have had any influence upon the number of molts is entirely beyond our power to determine. But, as will be pointed out in another connection, the writer believes that the conditions in the insectary as provided during these investigations was near enough natural conditions not to produce any unusual results.

It is obviously impossible to follow the number of molts of an insect such as the southern corn bill bug under perfectly natural conditions, as normally it lives within its food plant.

TABLE X. LARVAL DEVELOPMENT.

Record Number	Date of Hatching	Date of Shedding				Date of Pupating	Number Days Larval Stage
		1st Molt	2d Molt	3d Molt	4th Molt		
1	June 3	?	June 24	?	July 13	July 22	48
2	June 4	?	?	?	July 1	July 8	34
3	June 4	?	?	?	?	July 8	34
4	June 8	June 13	June 26	July 6	July 11	July 19	40
5	June 9	?	?	?	July 4	July 14	35
6	June 8	June 13	June 20	?	July 1	July 11	32
7	June 9	?	?	?	?	July 9	30
8	June 9	June 16	?	?	July 1	July 7	28
9	June 9	June 15	June 20	June 24	July 1	July 6	27
10	June 10	June 15	?	July 11	July 16	July 24	44
11	June 9	June 15	?	June 24	July 3	July 13	34
12	June 11	June 15	June 24	Jun 28	July 6	July 16	35
13	June 10	June 16	June 20	?	July 1	July 10	30
14	June 11	?	?	?	July 3	July 10	29
15	June 11	?	June 22	June 28	July 6	July 19	38
16	June 13	June 20	June 28	July 3	July 11	July 19	36
17	June 13	?	?	?	?	July 20	37
18	June 13	?	June 24	June 29	July 8	July 17	34
19	June 15	June 20	June 26	July 3	July 6	July 15	30
20	June 15	June 22	June 26	?	July 6	July 12	27
21	June 16	June 22	June 26	July 3	?	July 12	26
22	June 16	June 20	June 24	June 28	July 11	July 18	32
23	June 16	?	June 27	July 1	July 13	July 26	40
24	June 22	June 26	June 30	July 5	July 11	July 18	26
25	June 22	?	July 5	?	July 26	Aug. 7	47
26	June 22	June 29	?	?	July 11	July 22	30
27	June 22	June 29	July 3	July 12	July 20	Aug. 3	42
28	June 22	June 26	June 29	?	?	July 29	37
29	June 22	June 29	July 5	July 11	July 16	July 25	33
30	June 22	June 29	July 3	July 7	July 16	July 21	29
31	June 22	June 28	July 3	July 7	July 17	July 25	33
32	June 22	June 27	July 1	July 6	?	July 22	30
33	June 23	June 28	July 3	July 6	July 18	July 29	36
34	June 23	June 27	June 30	?	July 12	July 19	26
35	June 23	June 28	?	July 11	July 17	July 24	31
36	June 24	June 29	July 3	July 7	July 15	Aug. 17	54
37	June 26	?	July 5	July 11	July 15	July 25	29

Record Number	Date of Hatching	Date of Shedding 1st Molt	Date of Shedding 2d Molt	Date of Shedding 3d Molt	Date of Shedding 4th Molt	Date of Pupating	Number Days Larval Stage
38	June 26	July 1	July 6	July 11	July 17	Aug. 1	36
39	June 27	July 3	July 6	July 11	July 18	July 26	29
40	June 27	July 3	July 6	July 11	July 17	July 25	28
41	June 27	?	?	?	?	Aug. 3	37
42	June 27	?	?	?	?	July 31	34
43	June 28	?	?	?	?	July 26	28
43	June 28	?	?	?	?	July 26	28
44	June 28	?	July 12	July 17	July 26	Aug. 10	43
45	June 28	?	?	?	?	July 24	26
46	June 28	?	?	?	?	July 26	28
47	June 28	?	?	?	July 22	Aug. 2	35
48	June 28	July 4	?	?	?	July 27	29
49	June 29	?	?	?	July 23	Aug. 5	37
50	July 4	?	?	?	?	July 29	30
51	July 2	?	July 12	?	?	July 31	28
52	July 2	?	July 12	July 17	July 20	Aug. 5	34
53	July 5	?	July 17	July 22	July 26	Aug. 10	36
54	July 5	?	?	?	July 26	Aug. 6	32
55	July 7	July 13	July 17	July 20	?	Aug. 2	26
56	July 8	?	July 17	July 23	July 29	Aug. 10	33
57	July 8	?	July 19	July 23	July 29	Aug. 10	33
58	July 8	?	?	?	?	Aug. 7	30
59	July 8	?	July 19	July 22	July 27	Aug. 5	28
60	July 8	?	July 17	July 21	July 29	Aug. 10	33
61	July 12	?	?	Aug. 1	Aug. 10	Aug. 18	37
62	Aug. 3	?	?	Aug. 28	Sept. 5	Sept. 18	46
63	Aug. 7	?	Aug. 19	Aug. 24	Sept. 4	Sept. 12	36
64	June 2	?	?	?	?	July 14	42
65	July 8	?	July 17	July 24	July 31	Aug. 16	39
66	July 8	?	?	?	?	Aug. 11	34
67	June 10	June 16	July 20	July 1	July 5	July 13	33
68	June 9	?	?	July 8	July 11	July 19	40
69	June 22	?	July 5	July 16	July 18	Aug. 3	42
70	June 22	June 26	June 30	?	?	July 27	35
71	June 22	?	?	?	?	Aug. 14	53
72	June 23	?	?	?	?	July 20	27
73	June 26	July 1	?	?	?	July 31	35
74	July 24	?	?	?	?	Aug. 23	30
75	July 24	?	?	?	?	Aug. 26	33
76	Aug. 3	?	?	?	?	Sept. 11	37
77	Aug. 3	?	?	?	?	Aug. 26	23
78	Aug. 3	?	?	?	?	Aug. 26	23
79	Aug. 11	?	?	?	?	Sept. 6	26
80	Aug. 11	?	Aug. 27	?	?	Sept. 4	24
81	Aug. 28	?	?	?	?	Sept. 27	30
82	May 25	May 30	June 1	June 8	June 13	July 10	46
83	May 26	June 3	June 8	June 13	June 20	July 5	40
84	June 1	June 9	June 13	June 17	June 23	July 7	37
85	June 1	June 9	?	June 16	June 21	July 1	30
86	June 5	June 11	June 17	June 22	June 28	July 13	38
87	June 5	June 11	June 14	June 18	July 24	July 13	38
88	June 7	June 12	June 15	?	June 1	July 11	34
89	June 8	June 16	June 20	June 26	July 1	July 14	36
90	June 8	June 12	June 15	June 20	June 25	July 19	41
91	June 9	?	June 16	June 20	June 25	July 9	30
92	June 10	June 14	?	June 20	June 27	July 13	33

Record Number	Date of Hatching	Date of Shedding				Date of Pupating	Number Days Larval Stage
		1st Molt	2d Molt	3d Molt	4th Molt		
93	June 11	June 14	June 18	June 23	June 29	July 13	32
94	June 11	June 14	June 17	June 21	June 27	June 18	37
95	June 11	June 15	June 18	June 22	June 28	July 14	33
96	June 12	June 15	June 18	June 24	June 27	July 13	31
97	June 12	June 15	June 19	June 23	June 29	July 19	37
98	June 13	June 17	June 22	June 25	July 2	July 14	31
99	June 14	June 18	June 20	June 25	?	July 6	32
100	June 14	June 17	June 20	June 25	?	July 8	24
101	June 15	June 19	June 22	June 27	July 5	July 18	33
102	June 15	June 18	June 22	June 3	July 3	July 18	33
103	June 15	June 18	June 22	June 25	July 1	July 14	29
104	June 15	June 22	June 27	July 3	July 8	July 19	34
105	June 15	June 18	June 22	June 25	July 4	July 17	32
106	June 15	June 19	June 22	June 26	July 2	July 15	30
107	June 15	June 19	June 22	June 27	July 3	July 15	30
108	June 15	June 19	June 22	June 26	July 1	July 11	26
109	June 16	June 20	June 22	June 27	July 5	July 13	27
110	June 16	June 20	June 24	June 30	?	July 19	33
111	June 16	June 22	June 24	June 28	July 4	July 24	38
112	June 17	June 22	June 24	June 29	July 4	July 18	31
113	June 17	June 20	June 23	June 29	July 5	July 22	35
114	June 17	June 20	June 24	June 28	July 4	July 25	38
115	June 17	June 22	June 25	June 29	July 4	June 17	30
116	June 18	June 20	June 24	June 29	July 3	July 17	29
117	June 18	June 22	June 24	June 29	July 4	July 20	32
118	June 18	June 22	June 27	July 2	July 8	Aug. 1	44
119	June 18	June 22	June 26	July 1	July 8	July 24	36
120	June 18	June 22	June 27	July 1	July 8	July 21	33
121	June 18	June 22	June 25	June 25	?	July 14	26
122	June 19	June 22	June 27	July 2	July 11	July 24	35
123	June 19	June 22	June 25	June 29	July 6	July 20	31
124	June 19	June 22	June 25	July 1	?	July 19	30
125	June 19	June 22	June 28	July 3	July 9	July 19	30
126	June 19	June 23	June 27	July 3	July 11	July 24	35
127	June 19	June 22	June 27	July 1	July 7	July 20	20
128	June 19	June 22	?	July 2	July 10	July 22	33
129	June 19	June 22	June 28	July 2	July 8	July 21	32
130	June 19	June 22	June 27	July 2	?	July 25	36
131	June 19	June 23	June	July 1	July 8	July 22	33
132	June 19	June 22	?	July 1	?	July 15	26
133	June 19	June 22	?	July 2	July 8	July 22	33
134	June 20	June 24	June 28	July 2	July 9	Aug. 6	47
135	June 20	June 25	June 28	July 3	July 11	July 27	37
136	June 20	June 23	June 28	July 2	July 8	July 21	31
137	July 20	?	June 29	July 2	July 11	July 25	35
138	June 21	?	June 28	July 2	July 8	July 22	31
139	June 22	June 25	July 1	July 6	July 15	July 20	28
140	June 22	?	June 30	July 5	July 15	Aug. 3	42
141	June 22	June 28	July 8	July 15	July 18	Aug. 8	47
142	June 22	June 27	July 2	July 7	?	July 24	32
143	June 23	June 28	July 4	July 7	July 12	July 30	37
144	June 23	June 28	July 2	July 18	July 25	Aug. 7	45
145	June 23	July 1	July 4	July 11	?	July 27	34
146	June 25	June 28	July 9	July 11	July 20	Aug. 7	43
147	June 26	?	July 4	July 11	July 16	July 31	35
148	June 26	July 3	July 9	July 20	July 24	Aug. 6	41

Record Number	Date of Hatching	Date of Shedding: 1st Molt	2d Molt	3d Molt	4th Molt	Date of Pupating	Number Days Larval Stage
149	June 27	July 1	July 4	July 11	July 17	Aug. 2	26
150	June 27	July 1	July 3	July 7	July 16	July 30	33
151	June 27	July 1	July 4	July 8	July 24	Aug. 3	37
152	June 27	July 1	July 5	July 12	?	July 24	27
153	June 27	July 1	July 4	July 9	July 24	Aug. 3	37
154	June 27	July 1	?	July 8	July 14	July 22	25
155	June 27	?	July 4	July 8	?	July 24	27
156	June 28	July 2	July 5	July 12	?	Aug. 5	38
157	June 28	July 2	July 5	July 9	?	July 21	23
158	June 28	?	July 5	?	July 21	July 30	32
159	June 28	July 2	July 7	July 12	?	Aug. 1	34
160	June 29	July 2	July 12	July 21	July 26	Aug. 10	42
161	June 29	?	July 5	July 12	July 22	July 26	27
162	June 29	July 3	July 12	July 17	July 26	Aug. 3	35
163	June 30	July 3	July 7	July 17	July 26	Aug. 3	34
164	June 30	July 3	July 8	July 20	?	Aug. 6	37
165	June 30	July 3	July 15	July 20	July 26	Aug. 9	40
166	June 30	July 3	July 8	July 17	?	Aug. 7	38
167	June 30	July 3	July 8	July 20	?	Aug. 3	34
168	June 30	?	July 8	July 15	?	July 31	31
169	July 1	July 10	July 15	July 22	July 27	Aug. 5	35
170	July 1	July 7	July 11	July 20	?	Aug. 14	40
171	July 1	July 9	July 15	?	?	July 30	29
172	July 2	July 9	July 15	?	?	Aug. 4	33
173	July 2	July 9	July 15	July 20	July 27	Aug. 12	41
174	July 2	July 5	July 12	July 15	July 21	Aug. 2	31
175	July 5	?	July 14	July 20	?	Aug. 2	28
176	July 5	July 9	July 15	July 22	July 30	Aug. 4	30
177	July 5	July 12	July 17	July 22	?	Aug. 6	32
178	July 5	July 9	July 15	July 18	July 26	Aug. 4	30
179	July 5	July 8	July 17	July 21	?	Aug. 4	30
180	July 5	July 9	July 15	July 22	?	Aug. 5	31
181	July 5	July 9	July 15	?	?	July 31	26
182	July 6	July 11	July 20	?	?	July 30	24
183	July 6	?	July 17	July 24	?	Aug. 10	35
184	July 7	July 16	July 18	July 26	Aug. 3	Aug. 14	38
185	July 7	July 12	July 17	July 26	July 30	Aug. 2	26
186	July 7	July 12	July 17	July 26	July 30	Aug. 8	32
187	July 7	?	July 20	July 26	?	Aug. 6	30
188	July 8	July 20	July 26	Aug. 2	Aug. 5	Aug. 18	41
186	July 8	July 14	July 20	July 26	?	Aug. 7	30
190	July 8	July 14	July 17	July 21	July 27	Aug. 9	32
191	July 8	?	July 22	July 22	July 30	Aug. 8	31
192	July 8	?	July 18	?	?	Aug. 2	25
193	July 8	July 15	July 18	July 22	?	Aug. 7	30
194	July 11	July 17	July 20	July 26	?	Aug. 6	26
195	July 11	?	July 20	July 26	?	Aug. 9	29
196	July 11	July 17	July 21	?	?	July 10	30
197	July 16	July 20	July 27	?	Aug. 4	Aug. 12	27
198	July 16	July 22	July 26	July 30	Aug. 6	Aug. 19	34
199	July 17	July 20	?	July 30	July 7	July 14	28
200	July 17	?	July 26	?	?	Aug. 14	28
201	July 17	July 21	Aug. 2	Aug. 8	Aug. 14	Aug. 29	43
202	July 17	July 21	July 27	?	?	Aug. 11	25
203	July 18	?	July 27	Aug. 2	Aug. 6	Aug. 25	38
204	July 20	?	July 30	Aug. 3	Aug. 7	Aug. 16	27

Record Number	Date of Hatching	Date of Shedding				Date of Pupating	Number Days Larval Stage
		1st Molt	2d Molt	3d Molt	4th Molt		
205	July 20	July 28	July 31	?	Aug. 6	Aug. 24	35
206	July 20	July 24	July 31	Aug. 3	Aug. 11	Aug. 24	35
207	July 20	?	July 30	Aug. 4	?	Aug. 24	35
208	July 20	July 24	July 31	Aug. 2	Aug. 6	Aug. 24	35
209	July 22	?	July 31	Aug. 7	Aug. 14	Aug. 21	30
210	July 22	?	July 31	Aug. 3	Aug. 9	Aug. 20	29
211	July 22	July 26	?	Aug. 7	Aug. 11	Aug. 23	32
212	July 22	?	July 31	?	Aug. 9	Aug. 21	30
213	July 24	July 31	Aug. 4	?	?	Aug. 16	23
214	July 26	July 31	Aug. 4	Aug. 9	Aug. 14	Aug. 29	34
215	July 26	?	Aug. 2	Aug. 4	?	Aug. 26	31
216	July 26	July 31	Aug. 2	Aug. 6	?	Aug. 29	34
217	July 26	July 31	Aug. 2	Aug. 4	Aug. 7	Aug. 29	34
218	July 26	July 31	Aug. 2	Aug. 6	Aug. 11	Aug. 23	28
219	July 27	July 31	Aug. 2	Aug. 6	?	Aug. 18	22
220	July 27	?	?	Aug. 4	Aug. 9	Aug. 26	30
221	July 27	July 31	Aug. 4	Aug. 6	Aug. 12	Aug. 22	26

DURATION OF THE MOLTS

(First Molt, Fig. 19)

In all, 150 first molts have been recovered from the 221 larvæ that have been reared from the egg to the pupa. The duration from the date of hatching to the first molt ranged from two to twelve days, the extremes occurring once each. The greatest number, 105 out of the 150 or approximately 70 per cent, molted between the third and fifth day. This is expressed graphically by the curve (Fig. 32). From these figures it seems safe to conclude that usually the first molt occurs some time between the third and fifth day from the hatching of the egg, but it may be greatly prolonged, due, perhaps, in most cases to poor food, and first molts occurring six, seven, and eight days after hatching are not usual, and the first molt may occur as long as twelve days after hatching.

There is perhaps greater regularity in the occurrences of the first molt than there is in any of the succeeding molts, due, perhaps, to the fact that the larva has had less time than in its later molts to be influenced by its environment, especially by favorable or unfavorable food supply.

The other factor that cannot be neglected in this matter is the fact that any irregularities in the first or succeeding molts are of necessity cumulative, that is to say, the chances are that any larvæ that molt a few days early or a few days late in the first molt would also molt irregularly for the second and succeeding molts; hence these irregu-

larities would cumulate, and while individually they might be insignificant, yet when added to each other they have a tendency to throw our results away from the mean.

DURATION OF MOLTS

(Second Molt, Fig. 20)

There are two standards by means of which we may measure the duration of the second and succeeding molts. The first is the time that has elapsed since the first molt, and the second is the time that has

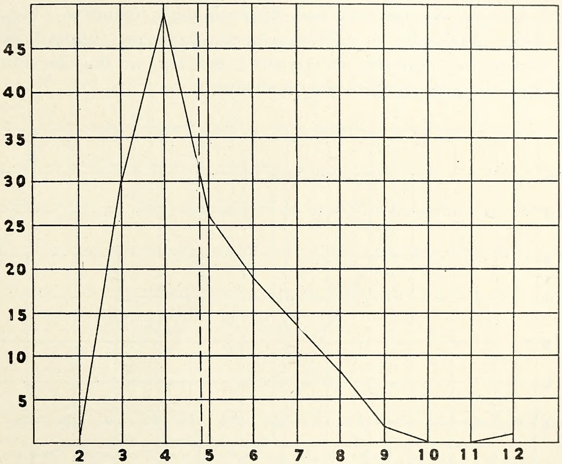


FIGURE 32. Curve showing the time lapsing between hatching and the first molt, one-day intervals. The mean time is shown by the dashed vertical line (— — — — —).

elapsed since the egg hatched. Both of these methods have been used and the results expressed graphically by the attached curves (Figs. 33 and 34).

The time elapsing between the first and second molts is comparable to the time elapsing between hatching and the first molt, the range extending from 2 to 13 days. The majority, 106 out of 134 or a little more than 79 per cent, however, molted the second time from 3 to 6 days after the first molt.

The duration in days from the time of hatching to the second molt is not nearly as uniform as it is in the first molt, the range in 175 larvæ being 6 to 21 days. However, 140 larvæ out of the 175 observed molted a second time between the sixth and eleventh days, making a total of

80 per cent for six days, as contrasted with a total of 70 per cent in three days for the first molt. In the larvæ observed there was practically no difference in the numbers (thirty-one, twenty-four, twenty-seven, twenty-five, and twenty) molting on the seventh to eleventh days, inclusive.

DURATION OF MOLTS

(Third Molt, Fig. 21)

The range in time from hatching to the third molt for 165 larvæ out of 221 larvæ bred from egg to purpa has been found to be from 8 to 31 days. The majority, however, 103 out of 165 or 62 per cent, molted between the eleventh and fifteenth days, inclusive (Fig. 35), there being practically no difference in the numbers (eighteen, twenty-two, twenty-two, nineteen, twenty-two) molting on the eleventh and succeeding days to the fifteenth, inclusive.

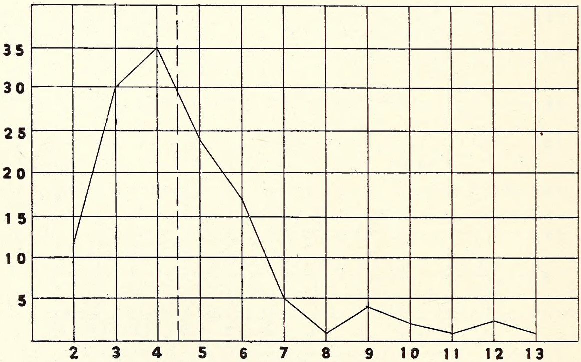


FIGURE 33. Curve showing the time lapsing between the first and second molts, one-day intervals. The mean time is shown by the dashed vertical line (— — — — —).

The time elapsing between the second and third molts is comparable to the time elapsing between hatching and the first molt and between the first and second molts, the range extending from two to sixteen days (Fig. 36). There was, however, only one larva out of 152 larvæ that required sixteen days between the second and third molts and none requiring thirteen, fourteen, or fifteen days. Hence this one larva may be discarded, giving us a range of from two to twelve days. These figures are very closely comparable to those found for the time elapsing between hatching and first molt and between first and second molt. In all, 115 out of the 152, or more than 75 per cent, molted for the third time between the third and sixth days after the second molt; the only

striking point being the larger number, 83 or more than 54 per cent of the total number, molted between the fourth and fifth days after the second molt.

DURATION OF MOLTS

(Fourth Molt, Fig. 22)

The time elapsing between third and fourth molts ranges from 2 to 15 days (Fig. 37). Ninety out of the 130 larvæ, or about 70 per cent, molted between the fifth and eighth days, inclusive. Six days in this case is more pronounced than in any of the other curves for lapsed time (see Figs. 32, 33, and 36).

The total time from hatching to the fourth molt ranges from 12 to 40 days, and there is a great tendency to variation (Fig. 38). The principal mode seems to occur around the nineteenth day.

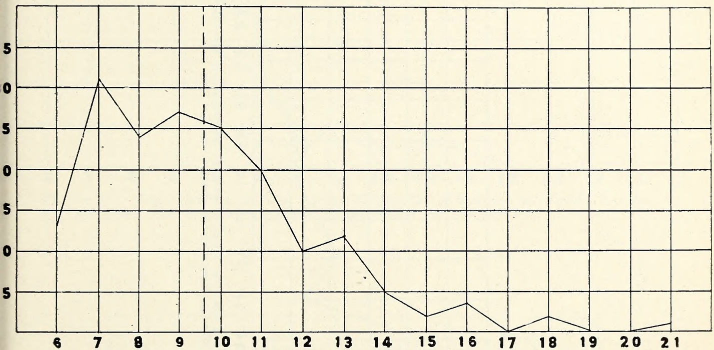


FIGURE 34. Curve showing the time lapsing between hatching and the second molt, one-day intervals. The mean time is shown by the dashed vertical line (— — — — —).

DURATION OF MOLTS

(Fifth Molt, Fig. 30)

(From fourth larval molt to pupation.)

The time between the fourth larval molt and pupation (fifth molt) is decidedly longer than that recorded for previous molts, ranging from three to thirty-one days. For the 149 larvæ for which we have been able to obtain the fifth-molt interval, there seems to be a tendency for the results to group themselves around two modes, one at 8 days and the other at 13 days. The mean, however, is 12.4 days, suggesting that the latter is perhaps the true mode, and that the apparent mode at 8 days is due to insufficient numbers (Fig. 39).

The total time for larval development, *i. e.*, from hatching to pupation, ranges from 22 to 54 days (Figs. 40 and 41). The majority,

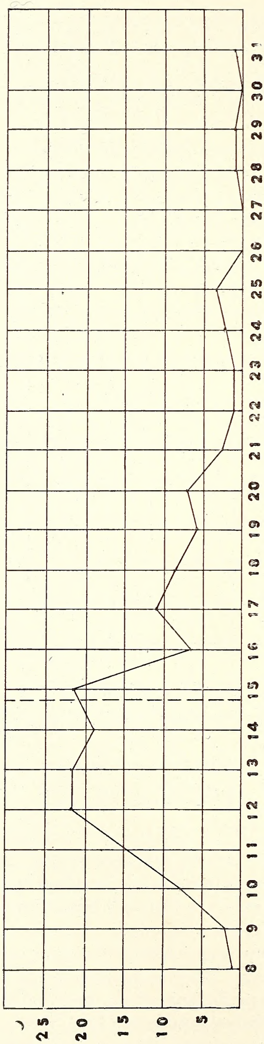


FIGURE 35. Curve showing the time lapsing between hatching and the third molt, one-day intervals. The mean time is shown by the dashed vertical line (— — — —).

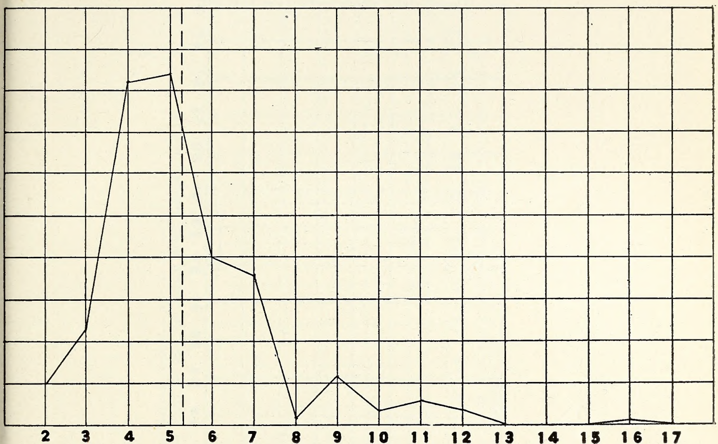


FIGURE 36. Curve showing the time lapsing between the second and third molts, one-day intervals. The mean time is shown by the dashed vertical line (— — — —).

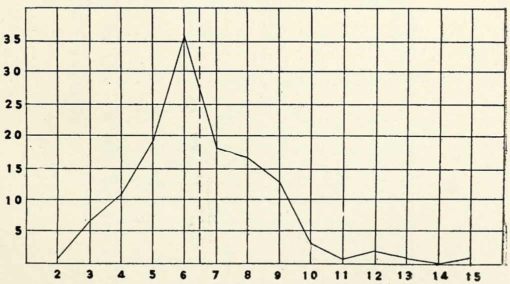


FIGURE 37. Curve showing the time lapsing between the time and fourth molts, one-day intervals. The mean time is shown by the dashed vertical line (— — — — —).

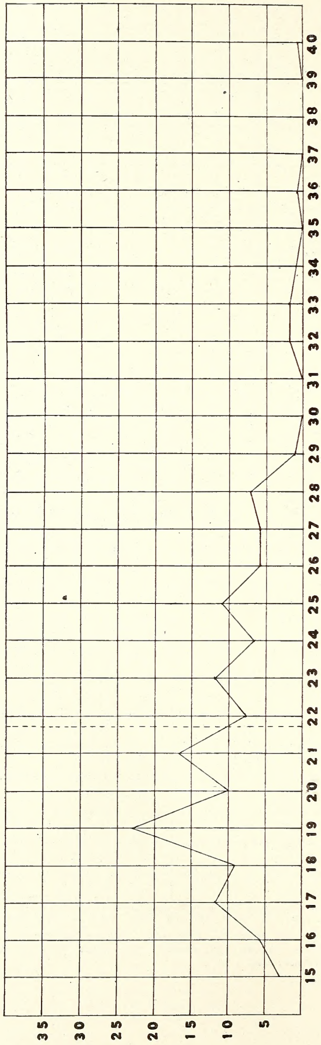


FIGURE 38. Curve showing the time lapsing between hatching and the fourth molt, one-day intervals. The mean time is shown by the dashed vertical line (— — — — —).

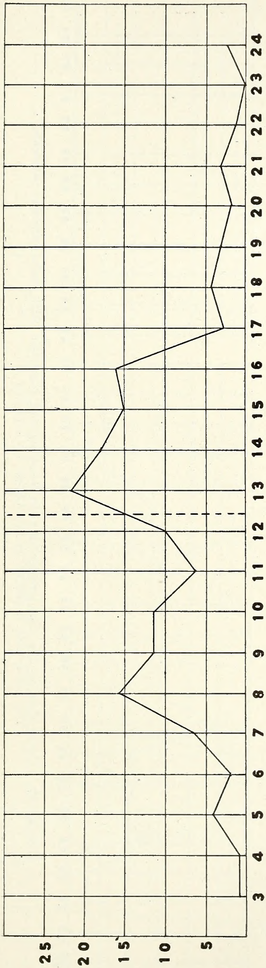


FIGURE 39. Curve showing the time lapsing between the fourth molt and pupation (fifth molt), one-day intervals. The mean time is shown by the dashed vertical line (— — — — —).

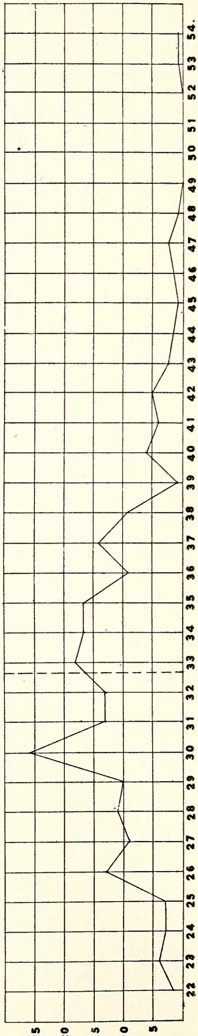


FIGURE 40. Curve showing the time lapsing between hatching and pupation (fifth molt), one-day intervals. The mean time is shown by the dashed vertical line (— — — — —).

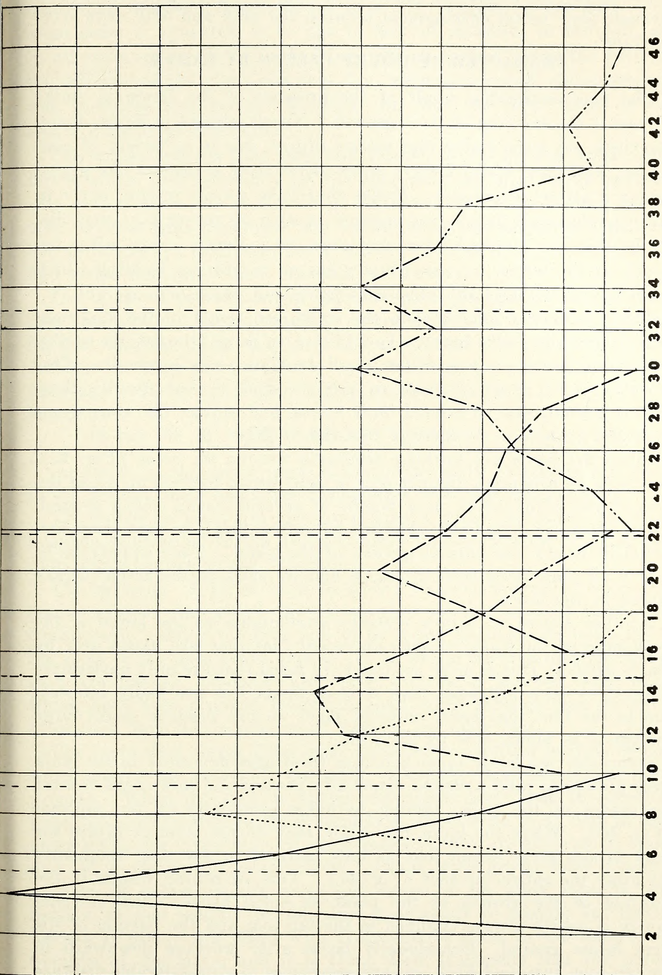


FIGURE 41. Curves showing larval development by molts, two-day intervals from hatching. Solid line first molt (————). Dotted line (. . . . .) second molt. Dashed and dotted line (— . — . —) third molt. Dashed line (— — — — —) fourth molt. Dashed and dots (— . . — . . —) fifth molt. The mean time for each molt is shown by the dashed vertical lines (— — — — —).

however, 169 out of the 221 larvæ observed, or about 77 per cent, passed through their larval development between the 26th and 37th days after hatching.

CHARACTER OF INJURY CAUSED BY LARVÆ

The most noticeable result of the presence of the larvæ in stalks of corn is the stunting of their growth. Nearly always in fields of any size there are some stalks that escape injury, due to a variety of conditions, and these stalks always tower above their neighbors like giants among a group of pigmies. Stalks that have worms present early in their development usually are injured to such an extent that they die. Stalks that are attacked later may grow to a certain extent after the attack by the larvæ, but one usually has no trouble in deciding which stalks in a given field are infested by larvæ and which ones are not.

These secondary effects upon the stalks are found in the abnormal growth that the stalks make. In addition to being stunted, the stalks, in severe attacks, are twisted out of all semblance to a cornstalk. This usually results in an attempt to produce suckers, but usually these suckers are not able to expand their leaves, and appear like some great abnormal growth on the sides of the stalk. (Figs. 42, 43, and 44.)

When the larvæ are working externally around the roots (Fig. 45), they seem to produce a distinct scar or split which extends up along the side of the plant, often to a height of several inches above ground. These scars are frequently shallow, but often they are very deep and seriously retard the normal growth of the plant. They appear to be out of all proportion both in length and in depth to the actual injury caused by the larvæ.

Another source of injury directly attributable to the larvæ is the weakening of the stalks to such an extent that they are blown over by heavy winds. This is more noticeable in fields that are only moderately infested by corn bill bugs than it is in fields that are badly infested, due to the fact that badly infested fields do not produce stalks large enough to be blown over by the wind.

Internally the larvæ upon hatching from eggs deposited in the stalk seem always to take a course diagonally inward and downward toward the center of the stalk, coming to lodge eventually in the tap-root (Fig. 46). While the larvæ are small, they do not seem to injure the stalk to any great extent, but as they increase in size they frequently eat away the entire tap-root (Fig. 47). This, of course, results in the stunting of the growth of the plant as noted above. This internal injury is nearly always confined to the tap-root and the portion of the stem below ground. Occasionally larvæ after working downward to the tap-root, turn and work upward sometimes to a considerable distance above ground. The causes behind such behavior are difficult to determine, as it certainly is not always due to a lack of food, for frequently larvæ will work upward in stalks where there is an abundance of food

below ground, and again larvæ have been found in the tap-root where the entire root had been reduced to a dry reddish brown pulp. In some cases it appeared to be due to lack of moisture in the soil, as in all cases where the larvæ had been driven to feed above the ground the soil around the plant was very dry, whereas the stalk above ground was succulent and green. Whether this was the only factor is of course difficult to determine.

The writer believes that eggs laid loosely in the ground hatch into larvæ which feed externally on the roots and the stem below ground and do not enter the stalk. Some of these externally feeding larvæ may be from eggs that were laid in the stalk, the larvæ on hatching boring downward until they leave the tap-root, as it is not unusual to find stalks that larvæ have deserted in this way.

The larvæ, of course, always do much more damage to stalks of corn than the adults. This is exactly contrary to popular belief, due to the fact that the adults are more or less exposed and are more or less familiar to most farmers in the corn bill bug sections of the State, whereas the larvæ are hidden within the stalk and are not at all well known.

HABITS OF THE LARVÆ

Inasmuch as the larvæ work either in the stalk or among the roots in the ground, their habits are rather hard to follow consecutively.

The following notes are presented from a study of several hundred individuals collected in the field and from a more detailed study of the individuals reared in the laboratory.

The majority of larvæ seem to prefer to feed internally upon the tender growth just above the tap-root or in the tap-root itself. A considerable number of larvæ are to be found feeding externally upon the roots or the stem below ground. The writer believes that the larvæ that are feeding extenally are larvæ that have hatched from eggs which have been dropped loosely, a habit adult females seem to have after they have laid a number of eggs in the same day.

The larvæ that hatch from eggs deposited in cavities burrow downward toward the center of the stalk, enlarging their tunnels as they proceed. When the stalk is young and tender they seem to consume practically everything in their tunnels as they come to it, but in the older stalks the larvæ tear off large pieces, which are reduced to frass and left in the tunnel behind them. As the larva grows older it seems to tear off proportionally more and more of the stalk than it can devour, so that usually by the time it is ready to pupate the larval burrow is pretty well filled with fragments of stalk in the immediate vicinity of the larva, and it is from these fragments that the pupal cell is constructed.

The larva is capable of comparatively rapid movements when disturbed, but normally it does not seem to move very far from the end

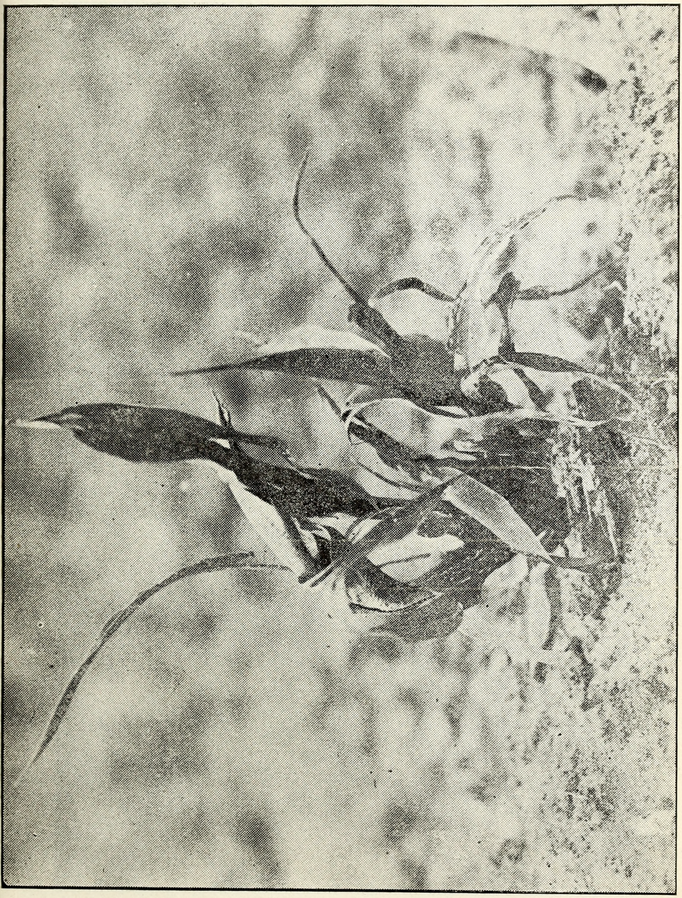


FIGURE 43. Corn plant showing characteristic inury caused by larvæ.

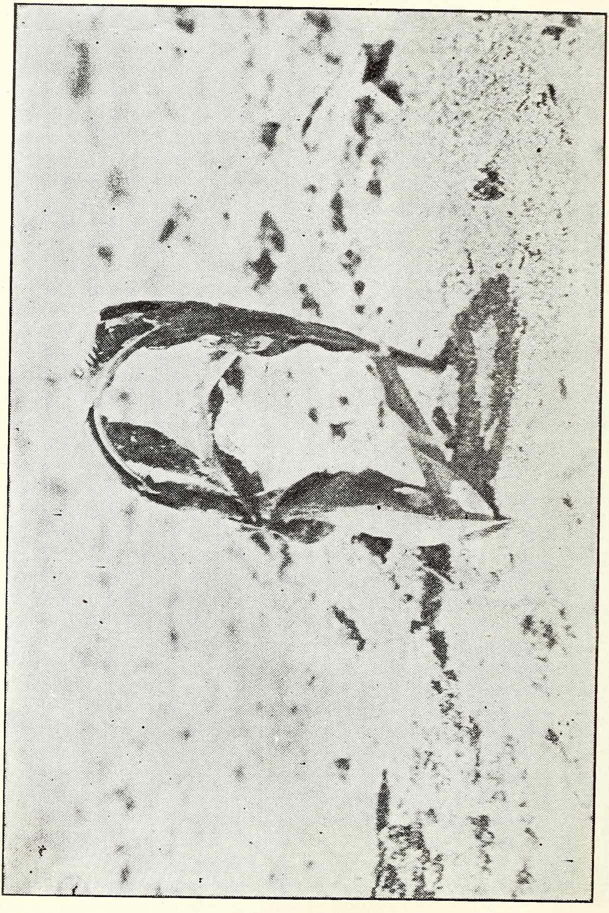


FIGURE 44. Corn plant injured by larvæ.

Figure 45. Larva working among the roots of corn.

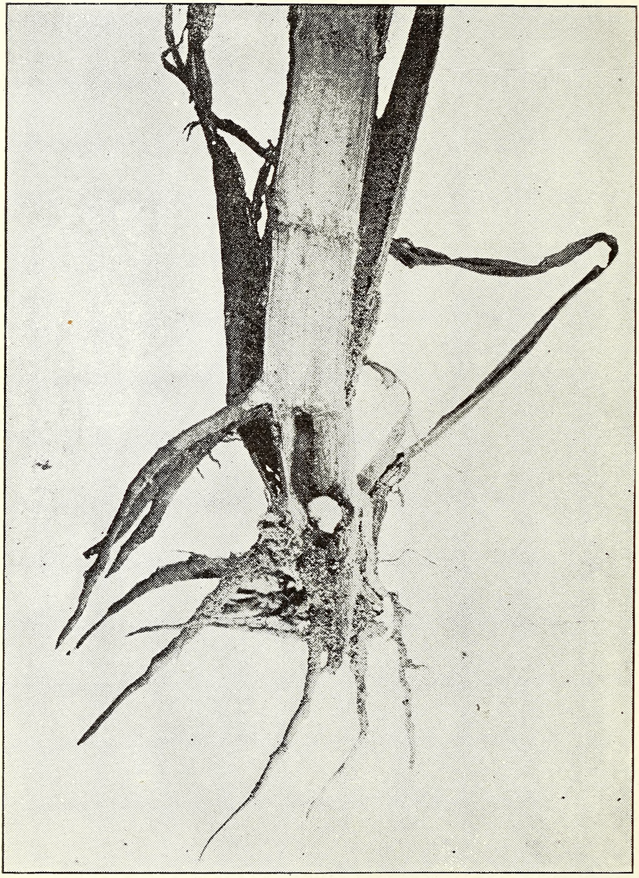


FIGURE 46. Larva in stalk of corn showing burrow.

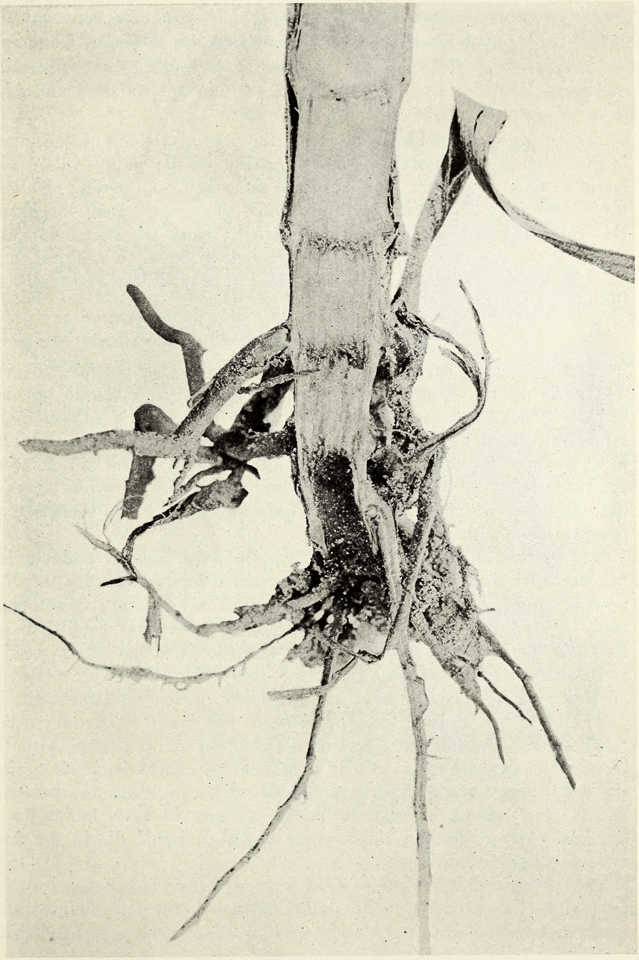


FIGURE 47. Corn plant showing injury to tap-root by larva.

of its tunnel where it is feeding. In the insectary the larvæ in the first day or two after hatching are capable of constructing an enormous length of tunnel, comparatively speaking. It is nothing unusual for one of these small larvæ less than two milimeters in length to burrow four or five times the length of a section of cornstalk seventy-five milimeters in length in a single day, or more than one hundred and fifty times its own length.

The turning and twisting habits of the prepupal stage of the larvæ is given in the discussion of the formation of the pupal cells. The larvæ as they prepare to molt have the same habit of turning about in their burrows. This most certainly helps them very much in getting rid of the old cast skin, as the larvæ usually work themselves forward at the same time they are turning; thus they travel in a spiral, and the cast skins are gradually worked backward and left eventually in the tunnel behind.

MORTALITY DURING LARVAL STAGE

In our breeding cages we have tried, in as far as possible, to give the larvæ natural conditions and at the same time make it possible to observe the larvæ from day to day. This undoubtedly subjected the larvæ to conditions which must have been in part, at least, adverse to their best development. On the other hand, larvæ which were observed every day completed their development in the same average time as larvæ which were disturbed only as often as was necessary to provide them with fresh food.

During the summer of 1915, 265 larvæ were isolated and studied for mortality data. These larvæ were treated in the ordinary way for rearing larvæ save that they were disturbed only when it was necessary to give them fresh food. The most unnatural condition introduced, so it seemed to the writer, was the fact that the pieces of cornstalks sometimes became slightly soured before they were replaced. In a few cases it seemed that natural decay, which sometimes sets in overnight in our climate, was the cause of the death of the larvæ, but other larvæ were able to withstand a condition which seemed actually identical in every respect. So it seems we are safe in concluding that the conditions were perhaps comparable with conditions in the field, and for the present, at least, we might say that no more larvæ die in the laboratory under the above conditions than would die in the field under natural conditions.

Therefore the following figures are presented for what they are worth. Of the 265 larvæ tested for this point, 138 passed through their various molts and were able to pupate; in other words, a mortality of slightly more than 45 per cent from egg to pupa.

In our regular breeding cages, where an atempt was made to secure every molt, 119 larvæ out of 276 died before they were able to pupate.

These were distributed as follows: 53 larvæ died before passing first molt, 18 larvæ before passing second molt, 14 larvæ before passing third molt, 14 larvæ before passing fourth molt, and 20 larvæ before passing fifth molt or pupating. This gives a total mortality from egg to pupa of slightly more than 43 per cent; figures in every way comparable to those above.

DESCRIPTION OF THE PUPA

Pupa stout, naked, soiled whitish in color, a typical rhynchorphorus pupa with the following minor points (Figs. 48, 49, and 50).

Ventral view: rostrum stout, reaching between the first pair of tibia, with three pairs of prominent tuberculate hairs on the base; antennæ elbowed, almost equaling the front femora; eyes not prominent; legs sub-equal in length, the hind pair covered by the wings, each femora with a stout hair near its distal end, tarsi not distinctly jointed, wings with prominent longitudinal ridges; five stout tuberculate hairs on the eighth ventral segment of the abdomen.

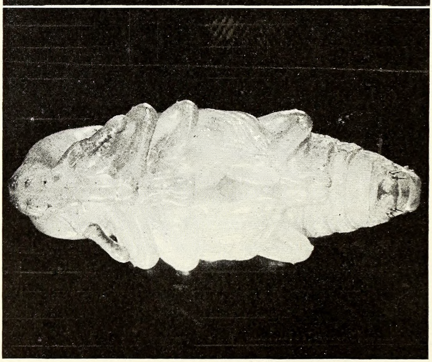
Lateral view: head deflexed; prothorax depressed anteriorly, usually with two short tuberculate spines, one about middle of anterior half and the other about middle of posterior half; prothracic spiracles large; wings prominent, curving ventrally between second and third pairs of legs, covering basal half of hind femora, with ten prominent longitudinal ridges; first six abdominal spiracles rather prominent, the others not evident, four long hairs on the dorsal part of the eighth abdominal segment.

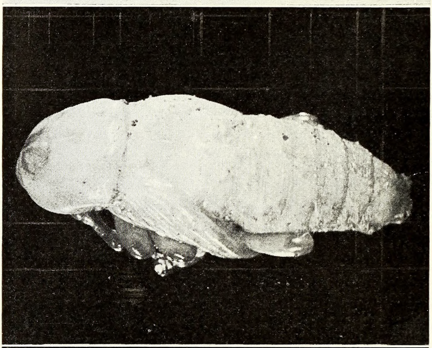
Dorsal view: head nearly concealed by the prothorax; meso-thorax and meta-thorax distinct, the former terminating posteriorly in a prominent triangular lobe between the wings; the first to sixth abdominal segments nearly equal in size, with two groups of slender tuberculate marginal hairs either side of the median line, the hairs in either group about equidistant from each other, four in number; laterally there is a single tuberculate hair about mid-distant between the spiracle and the marginal group of tuberculate hairs; the seventh abdominal segment destitute of hairs save a single lateral pair; the eighth with the four pairs of hairs as described above.

SIZE OF PUPÆ

In all, twenty pupæ were measured, selected at random throughout the season. Two measurements were taken; the total length measured while the pupa was resting on a flat surface and the width across the mesothoracic legs measured from patella to patella. These measurements are given in Table XI below.

The extremes in length being 11.08 mm. and 15.74 mm., the average being 12.99 mm. The width varied from 5.08 mm. to 6.43 mm., the average being 5.69 mm.





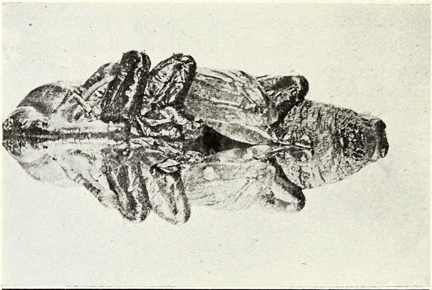


FIGURE 48. Young pupa, ventral view. X6. FIGURE 49. Dorso-lateral view of young pupa. X6. FIGURE 50. Old pupa, ventral view. X6.

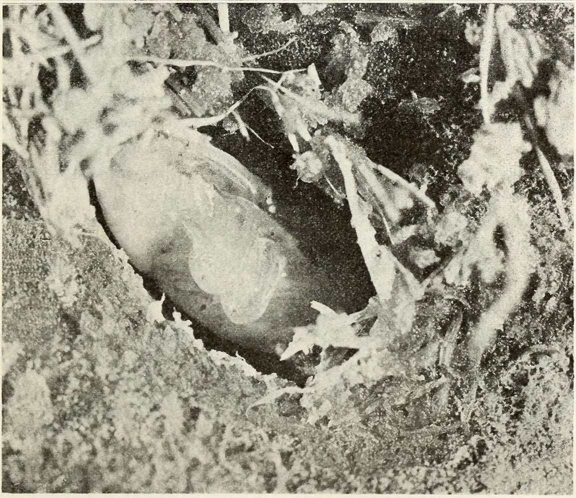


Figure 51. Pupa in pupal cell, lateral view. X6.

Figure 52. Pupa in pupal cell, dorsal view. X6.

TABLE XI.

MEASUREMENTS OF 20 PUPÆ OF THE CORN BILL BUG.

Number	Total Length in mm.	Width Across Mesothoracic Legs in mm.
1	13.87	6.17
2	15.74	6.43
3	12.26	2.56
4	13.56	6.13
5	14.39	6.04
6	12.65	5.47
7	11.39	5.26
8	12.56	6.17
9	12.56	5.56
10	11.08	5.08
11	13.39	5.95
12	14.30	6.13
13	13.56	5.65
14	11.30	5.30
15	12.95	5.86
16	12.13	5.13
17	13.48	5.26
18	13.08	6.08
19	12.95	5.30
20	12.65	5.65

PUPAL CELLS

In our work in the insectary and laboratory the larvæ when they became full grown formed a compact oblong-ovoid cell in the stalk of corn, using partly masticated pieces of the cornstalk to plug the larval burrow and compacting the whole by interminable turnings and twistings as noted above (Figs. 51, 52, 53, and 54). In these cells the pupa fit loosely.

In the field some pupal cells are formed in the stalks of corn and some are formed in earthen cells in the soil just beneath the roots, usually about one inch deeper than the hole made when we pull a stalk up by the roots (Figs. 56 and 57). These cells made in the soil are smooth and compact internally, but are unlined for the most part. Occasionally one finds a pupal cell where the tap-root has been entirely eaten away; then the pupal cell may be lined with fragments of the well masticated tap-root. But so far as our observations go, the larvæ do not move material very far with which to make the lining of their pupal cells, but take whatever comes first to hand, be it either fragments of stalk or roots or particles of soil.

EFFECTS OF MOISTURE UPON THE PUPÆ

The pupæ seem to be little affected by moisture. They can be drowned by complete immersion in water, but anything much short of complete immersion seems to have little effect upon them. Neither does

the amount of moisture seem to have much effect upon the duration of the pupal stage. Pupæ kept in tight tin boxes with the air more than saturated with water emerged on the average in the same time as pupæ which were exposed to the dry air of an average room or those exposed to the average humidity out of doors in a screened insectary.

FIGURE 53. Pupal cells formed of corn fiber for protection of pupa; emply pupal cell on left was formed in the soil just beneath corn stalk in which the larva completed its growth. Pupal cell shown in corn stalk was in natural position at lower end of feeding cavity.

MORTALITY OF THE PUPA

Not as extensive figures have been kept on the mortality of the pupæ as upon the mortality of the larvæ. During 1915 147 pupæ were observed; from this number 110 adults were secured, giving a total mortality of slightly more than 18 per cent. Whether this is comparable to conditions as they exist in the field has not been determined. Observations made during the course of this project would lead one to believe, however, that this figure is somewhat high. The pupæ used in this experiment were not often disturbed, and frequently the stalks of corn became moldy or decay set in before they were observed again. Usually the mold or bacteria present infected the pupæ, causing their death in a majority of cases.

This condition must be wanting or very unusual in the field, for out of hundreds of pupæ observed in the field, both in cyperus and in corn, the writer has never seen a single decayed or moldy pupa. Hence it seems that we would be safe in concluding that a death rate of 18 per cent is abnormally high for pupæ.

DURATION OF THE PUPAL STAGE

In 1911 fifty-three adults were reared from pupæ whose larval stages had been followed. These all passed through the pupal stages in from eight to eleven days; the greater number maturing in nine days after they had pupated.

In 1915 one hundred and ten adults were reared from pupæ whose larval stages had been followed from the hatching of the egg. These matured in from four to twelve days; the greater number maturing in from seven to eight days.

From these figures it would seem safe to conclude that seven to nine days represent the normal length of the pupal stage; the time, perhaps, inclining somewhat toward the longer time, as is represented in Fig. 58.

As is mentioned elsewhere, variations in humidity seem to have very little effect upon the rapidity with which corn bill bugs pass through the pupal stage. The normal variations in temperature during the summer months seem to affect them only slightly, if at all, for the average time for pupæ reared in an out-of-doors insectary during July is practically the same as for pupæ reared in September.

The length of time required for larval development seems likewise to have no influence upon the time required for pupal development. In other words, the average time required for a bill bug with a total larval period of twenty to thirty days to pass through the pupal stages is so near the same as the average time required for bill bugs that have a total larval period of thirty to forty days or forty to fifty days that we seem safe in concluding that the length of the larval period has no influence whatever upon the length of the pupal period (Fig. 59).

TABLE XII.

DEVELOPMENT OF 53 PUPÆ, SEASON 1911.

Record Number	Larval Development—Number Days	Date of Pupating	Date of Emerging	Pupal Development—Number Days	Sex
1	48	July 22	July 31	9	Female
2	34	July 8	July 17	9	Female
3	34	July 8	July 16	8	Male
4	40	July 19	July 28	9	Female
5	35	July 14	July 22	8	Female
6	32	July 11	July 20	9	Male
7	29	July 9	July 18	9	Male
8	27	July 7	July 15	8	Female
9	26	July 6	July 14	8	Male
10	44	July 24	Aug. 3	9	Female
11	33	July 13	July 28	9	Female
12	36	July 16	July 24	8	Male
13	30	July 10	July 19	9	Female
14	30	July 10	July 19	9	Female
15	38	July 19	July 28	9	Male
16	35	July 19	July 28	9	Male
17	36	July 20	July 29	9	Female
18	33	July 17	July 26	9	Male
19	30	July 15	July 24	9	Female
20	26	July 12	July 21	9	Female
21	28	July 12	July 21	9	Male
22	32	July 18	July 26	8	Female
23	40	July 26	Aug. 5	10	Female
24	26	July 18	July 26	8	Female
25	47	Aug. 7	Aug. 15	8	Female
26	30	July 22	July 31	9	Female
27	42	Aug. 3	Aug. 12	9	Female
28	46	July 29	Aug. 7	9	Female
29	32	July 25	Aug. 4	10	Female
30	29	July 21	July 31	10	Female
31	33	July 25	Aug. 4	10	Female
32	30	July 22	July 31	9	Female
33	35	July 29	Aug. 7	9	Male
34	26	July 19	July 29	10	Female
35	30	July 24	Aug. 3	10	Female
36	53	Aug. 17	Aug. 26	9	Male
37	38	July 25	Aug. 3	9	Male
38	36	Aug. 1	Aug. 10	9	Male
39	28	July 26	Aug. 4	9	Male
40	27	July 25	Aug. 3	9	Male
41	37	Aug. 3	Aug. 12	9	Male
42	27	July 26	Aug. 4	9	Female
43	26	July 24	Aug. 3	10	Male
44	27	July 26	Aug. 4	9	Male
45	34	Aug. 2	Aug. 10	8	Female
46	29	July 27	Aug. 6	10	Female
47	30	July 29	Aug. 7	9	Female
48	34	Aug. 5	Aug. 14	9	Female
49	32	Aug. 6	Aug. 15	9	Female
50	26	Aug. 2	Aug. 11	9	Female
51	30	Aug. 7	Aug. 15	8	Female
52	36	Aug. 18	Aug. 27	9	Male
53	36	Sept. 12	Sept. 23	11	Female

TABLE XIII.

DEVELOPMENT OF 110 PUPÆ, SEASON OF 1915.

Record Number	Larval Development—Number Days	Date of Pupating	Date of Emerging	Pupal Development—Number Days	Sex
1	46	July 10	July 18	8	Female
2	30	July 5	July 13	8	Male
3	37	July 7	July 15	8	Male
4	38	July 13	July 19	6	Female
5	38	July 13	July 19	6	Male
6	34	July 11	July 18	7	Female
7	36	July 14	July 21	7	Male
8	30	July 9	July 17	8	Female
9	32	July 13	July 19	6	Female
10	37	July 18	July 27	9	Female
11	31	July 13	July 20	7	Female
12	37	July 19	July 26	7	Male
13	31	July 14	July 19	5	Female
14	22	July 6	July 13	7	Male
15	24	July 8	July 17	9	Male
16	29	July 14	July 24	10	Male
17	34	July 19	July 28	9	Female
18	32	July 17	July 28	11	Female
19	30	July 15	July 20	5	Male
20	26	July 11	July 17	6	Female
21	27	July 13	July 18	5	Male
22	33	July 19	July 26	7	Male
23	30	July 17	July 24	7	Male
24	29	July 17	July 24	7	Male
25	29	July 17	July 21	4	Male
26	32	July 20	July 28	8	Female
27	33	July 21	July 28	7	Male
28	26	July 14	July 21	7	Female
29	31	July 20	July 28	8	Female
30	35	July 24	July 31	7	Female
31	33	July 22	July 30	8	Male
32	32	July 21	July 29	8	Female
33	33	July 22	July 30	8	Female
34	26	July 15.	July 22	7	Male
35	33	July 22	July 30	8	Female
36	37	July 27	Aug. 3	7	Female
37	31	July 21	July 29	8	Male
38	35	July 25	Aug. 2	8	Male
39	28	July 20	July 29	9	Male
40	42	Aug. 3	Aug. 7	4	Male
41	47	Aug. 8	Aug. 16	8	Male
42	32	July 24	Aug. 1	8	Female
43	37	July 30	Aug. 5	6	Female
44	45	Aug. 7	Aug. 15	8	Male
45	34	July 27	Aug. 3	7	Female
46	43	Aug. 7	Aug. 14	7	Male
47	35	. uly 31	Aug. 7	7	Male
48	36	Aug. 2	Aug. 10	8	Female
49	37	Aug. 3	Aug. 11	8	Female
50	27	July 24	Aug. 1	8	Male
51	38	Aug. 3	Aug. 8	5	Female
52	27	July 24	Aug. 1	8	Male
53	37	Aug. 3	Aug. 8	5	Female
54	25	July 22	Aug. 29	7	Male
55	38	Aug. 5	Aug. 13	8	Male

Record Number	Larval Development—Number Days	Date of Pupating	Date of Emerging	Pupal Development—Number Days	Sex
56	23	July 21	July 29	8	Male
57	34	Aug. 1	Aug. 8	7	Female
58	42	Aug. 10	Aug. 18	8	Male
59	27	July 26	Aug. 2	7	Female
60	34	Aug. 3	Aug. 10	7	Male
61	37	Aug. 6	Aug. 14	8	Female
62	40	Aug. 9	Aug. 16	7	Female
63	38	Aug. 7	Aug. 14	7	Male
64	34	Aug. 3	Aug. 10	7	Female
65	35	Aug. 5	Aug. 13	8	Female
66	44	Aug. 14	Aug. 27	8	Female
67	29	July 30	Aug. 5	6	Male
68	41	Aug. 12	Aug. 20	8	Female
69	31	Aug. 2	Aug. 9	7	Female
70	28	Aug. 2	Aug. 8	6	Male
71	32	Aug. 6	Aug. 13	7	Female
72	30	Aug. 4	Aug. 12	8	Male
73	26	July 31	Aug. 7	7	Female
74	24	July 30	Aug. 5	6	Male
75	35	Aug. 10	Aug. 18	8	Female
76	48	Aug. 14	Aug. 22	8	Female
77	36	Aug. 12	Aug. 20	8	Female
78	32	Aug. 8	Aug. 15	7	Male
79	30	Aug. 6	Aug. 13	7	Male
80	41	Aug. 18	Aug. 25	7	Male
81	30	Aug. 7	Aug. 14	7	Female
82	32	Aug. 9	Aug. 16	7	Female
83	31	Aug. 8	Aug. 15	7	Male
84	25	Aug. 2	Aug. 8	6	Male
85	30	Aug. 7	Aug. 14	7	Female
86	26	Aug. 6	Aug. 13	7	Male
87	29	Aug. 9	Aug. 17	8	Female
88	30	Aug. 10	Aug. 18	8	Female
89	27	Aug. 12	Aug. 20	8	Female
90	34	Aug. 19	Aug. 27	8	Female
91	28	Aug. 14	Aug. 21	7	Female
92	28	Aug. 14	Aug. 21	7	Female
93	25	Aug. 11	Aug. 18	7	Female
94	38	Aug. 25	Sept. 6	12	Female
95	27	Aug. 16	Aug. 25	9	Male
96	35	Aug. 24	Sept. 2	9	Female
97	35	Aug. 24	Sept. 2	9	Male
98	35	Aug. 24	Sept. 2	9	Female
99	30	Aug. 21	Aug. 30	9	Female
100	29	Aug. 20	Aug. 29	9	Female
101	31	Aug. 23	Sept. 2	10	Female
102	30	Aug. 21	Aug. 29	8	Female
103	23	Aug. 16	Aug. 25	9	Male
104	34	Aug. 29	Sept. 7	9	Female
105	31	Aug. 26	Sept. 6	11	Female
106	34	Aug. 29	Sept. 8	10	Female
107	28	Aug. 23	Sept. 1	9	Male
108	22	Aug. 18	Aug. 29	11	Male
109	30	Aug. 26	Sept. 6	11	Female
110	26	Aug. 22	Aug. 31	9	Female

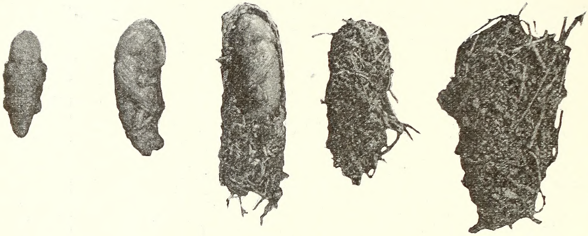


FIGURE 54. Pupæ and pupal cell formed of corn fiber; two small pupæ on left dorsal and lateral views; on right live pupa in its pupal cell. X2

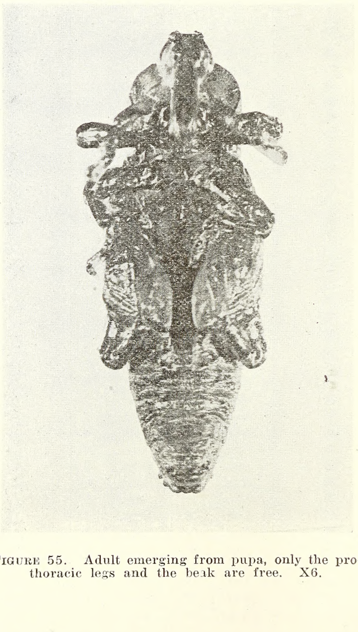


FIGURE 55. Adult emerging from pupa, only the prothoracic legs and the beak are free. X6.

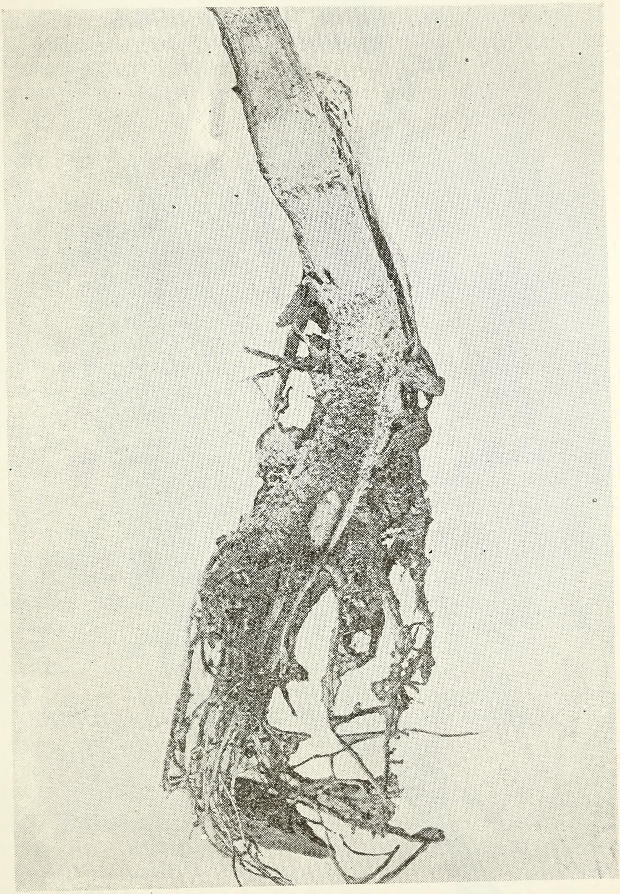


FIGURE 56. Pupa in pupal cell in tap-root. X1.

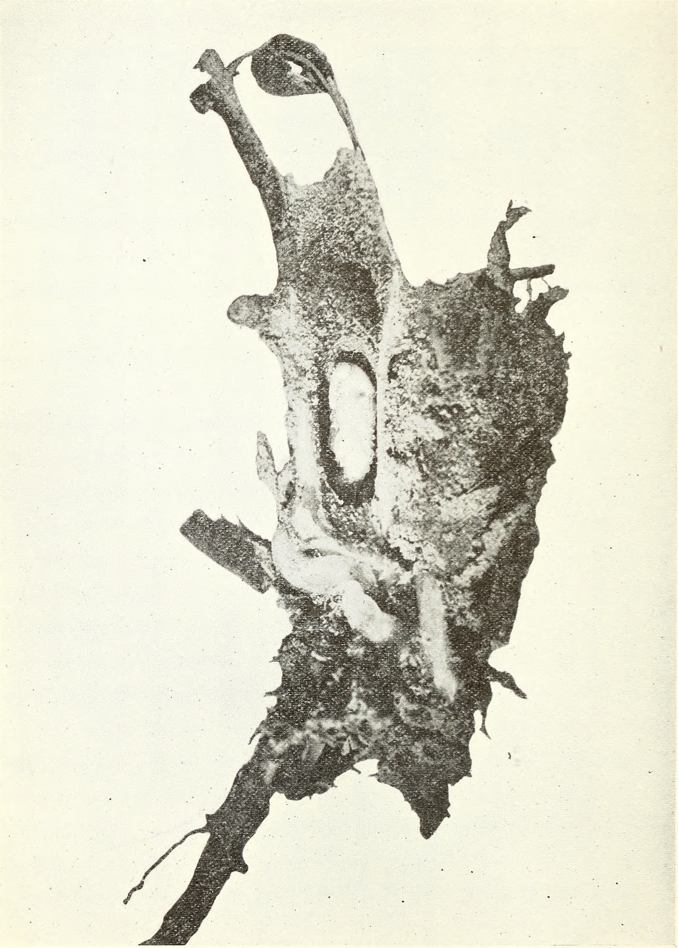


FIGURE 57. Pupa in pupal cell in ground among roots of corn stalk. X2.

TRANSFORMATION OF PUPA

The Molting of the Last Larval Skin

Usually about forty-eight hours before a larva is ready to transform to a pupa it ceases to feed, assumes a straight, rigid form (Fig. 29), and commences to turn over and over inside of the cell. This seems to compact the material with which the cell is lined and at the same time smooths the interior of the cell. This stage may be known as the prepupal stage, and larvæ usually assume this stage about forty-eight hours before they are ready to pupate. Cases have been observed, however, where the prepupal stage was assumed three days before pupation; in other cases, however, this stage is not assumed until the last day before pupation.

Just before pupation actually takes place the perfectly formed pupa may be distinguished through the transparent larval chitin. The larval chitin splits first along the epicranial and frontal sutures, and the prothorax is the first part of the pupa to emerge clearly from the cast skin, due to the fact that the head of the pupa is bent ventrally. Gradually the cast skin splits more and more posteriorly and is worked away from the body by the pupa turning and twisting its abdomen about (Fig. 31). The larval cast skin covering the legs and beak is the last to be freed from the pupa, this part of the cast skin frequently clinging to the pupa for several days. Usually the whole transformation from prepupa to pupa takes place in thirty minutes, sometimes, however, it takes longer than this. In one case observed the splitting of the larval cast skin commenced at 6 in the evening but the pupa did not have its abdomen free from the larval cast skin until the next day between 9 and 10 in the morning. Such occurrences must be rare, however, for the only other case observed, where it required the pupa longer than an hour or two to free itself from the larval skin, the pupa died before it was able to free itself, indicating that it was not normal.

The pupa is at first a pure translucent white, but in the course of a few hours it turns a pale straw yellow and retains this color until the developing adult's dark colored body can be seen through the translucent pupal skin (Figs. 48-50). This color can usually be noticed a day or two before the adult is ready to emerge.

HABITS OF THE PUPA

The pupa is naturally confined to its pupal cell. Therefore it has no habits that are especially interesting. When the pupa is disturbed it bends its abdomen first dorsally, then ventrally, and is thus able to rotate its body. It does not usually keep this process up very long before it relaxes. Usually the period of relaxation is approximately as long as the period of action which has just preceded. In most cases it takes a very violent disturbance to make the pupa become active before the period of relaxation has been of approximately the same

duration as the period of activity. These alternate periods of activity and relaxation seem to follow each other in fairly regular succession over long periods of time. I do not mean to imply by the above statements that there is any accurate mechanism which regulates the periods of relaxation with those of activity, but repeated observations showed that it took a much more violent stimulus to cause activity in a pupa that had recently relaxed than it did in a pupa that had been relaxed for some time. And apparently the longer the period of relaxation, the smaller the stimulus required to produce activity.

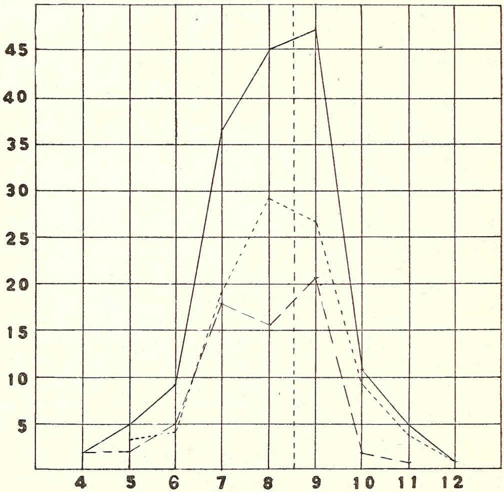


FIGURE 58. Curve to show duration of pupal stage. Dotted line (. . . .) females. Dashed line (— — —) males. Solid line (————) totals.

DESCRIPTION OF THE ADULT

The following description of the adult is summarized from Blatchley and Leng (1916), our most recent authorities on this group:

Tibiæ all broadly rounded at outer apical angle. Third joint of hind tarsi feebly dilated. Third joint of other tarsi not dilated, entirely glabrous beneath. Elytral intervals all flat, no single one of them in part or wholly distinctly elevated above the others. Beak curved, slender. Front tibiæ straight. Thorax with distinct smooth spaces. Median thoracic smooth area dilated at middle. Surface densely coated.

Oval robust. Black, densely clothed with a brownish or olivaceous clayey coating; antennæ and tarsi reddish-brown. Beak two-thirds the

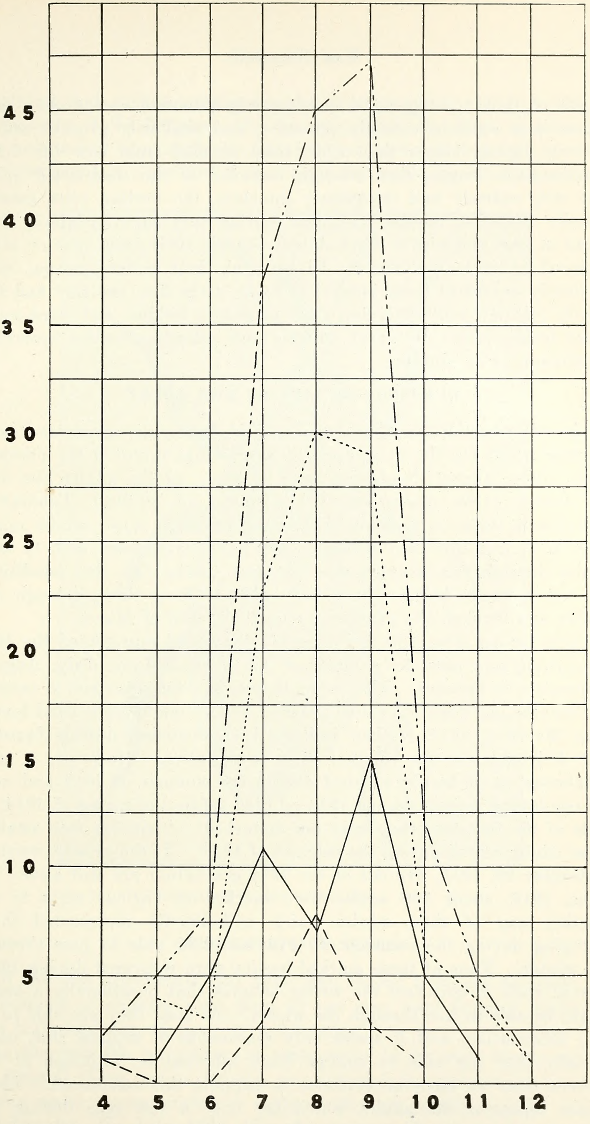


FIGURE 59. Curve to show the relation between duration of larval stage and duration of pupal stage. Solid line (————), pupæ whose larvæ required from twenty to thirty days to complete their development; dotted line (........) pupæ whose larvæ required from thirty to forty days to complete their development; dashed line (— — — —) pupæ whose larvæ required from forty to fifty days to complete their development; dashed and dotted line (—..—..—) totals for all pupæ observed.

length of thorax, compressed and sparsely punctate except near base, where it is swollen, coarsely punctate, and shallowly grooved above. Thorax slightly longer than wide, sides parallel from base for three-fourths their length, then strongly rounded to the constricted apex; disc very coarsely and irregularly punctate, the median vitta usually broadly dilated at middle, its apical portion very narrow; lateral vittæ broad at base and with a short oblique branch, their front portion often replaced by coarse punctures. Elytra oval, their surface uneven, sides gradually narrowed from humeri to apex; striæ fine, coarsely and distinctly punctate; intervals flat, their punctures hidden, and third sometimes feebly base. Humeral umbone and sub-apical callus somewhat prominent, often shining.

DURATION OF LIFE OF THE ADULT

The adult beetles found in any corn-field during the spring and early summer must, for the most part, be adults that matured the previous June, July, August, September, and October, as the adults live over the winter. (See discussion of hibernation of adults.) Laboratory experiments seem to indicate that occasionally, at least, adults might be able to live over two winters. We have never been able to keep adults through two winters, due, perhaps, to the fact that conditions are not normal; but we have been able to keep them through one winter and through the next winter until the first of March.

These beetles were collected June 20, 1910, and represented the 1909 generation, and must have matured the previous June, July, August, September, or October. They were, therefore, from seventeen to twenty-one months old when they died. These beetles might have lived longer than March 1, 1911, if they had not been disturbed during January and February to see whether they were alive. However, a miscellaneous lot of beetles hatched during the summer of 1912 and used for egg-laying records during 1913 all died before the spring of 1914, in spite of the fact that they were not disturbed. A similar fate awaited those adults reared during the summer of 1913. At the present writing, November 26, 1915, five out of the 1914 generation are still alive. In June, 1913, about 500 adults were marked in various ways to see whether any of these adults which undoubtedly represented those emerging during the summer of 1912 would be able to pass through the winter. None of these marked beetles were recovered during 1914. But in spite of this fact the writer believes that occasionally a beetle might be able to live through the winter. At least they are able to go into hibernation, and it seems only reasonable to suppose that occasionally they are able to emerge from hibernation, although at the present time we have no evidence to support this conclusion. These might represent the adults which lay only a few eggs during the summer (see egg-laying records above). At least, we have not been able to assign any other cause to the failure of certain adults to lay

anything that even approximates the average number of eggs laid by a majority of the females. On the other hand, the adult females that lay only a few eggs might be females that matured early the previous summer and laid a portion of their eggs during the previous season.

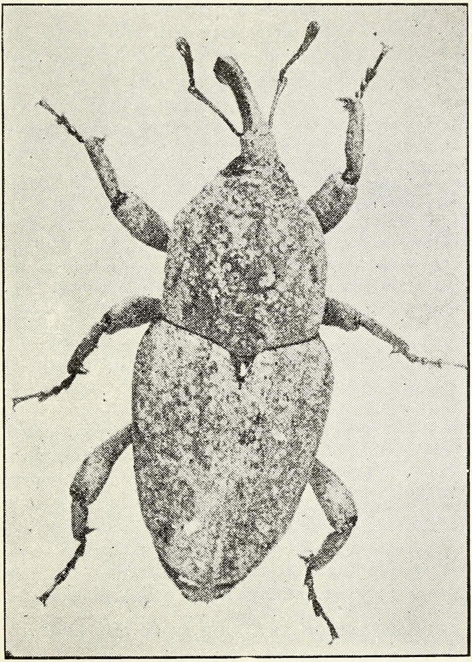


FIGURE 60. Adult dorsal view. X8.

PROPORTION OF SEXES

Of the 163 individuals that have been reared from egg to adult, 95 individuals or slightly more than 58 per cent were females, while 68 or a little less than 42 per cent were males.

In the field the proportion of sexes seems to be more nearly equal. As a usual thing, active females are attended by males, and inactive beetles under stones, sticks, or clods of dirt are usually equally males and females. In July, 1912, this point was made a special point for investigation, and in all 627 individuals were counted and so marked

as to prevent their being recounted. It is believed that this represents practically all of the bill bugs present on a plat of one-third acre. Of 627 individuals, 329 or slightly more than 52 per cent were females; while 298 or slightly less than 48 per cent were males. In addition to this, many other observations and the counting of smaller numbers of bill bugs would indicate that the proportion of sexes in the field was approximately equal. The table below will indicate the approximate numbers of bill bugs and their distribution as determined from counting all the bill bugs that could be found on a plat about one-eighth of an acre in extent as counted June 10, 1915, between 10 a. m. and 3 p. m. In this case over 60 per cent were males and less than 40 per cent were females. And while it is possible that some bill bugs may have been missed, an effort was made to secure all of the bill bugs present, and certainly the vast majority of the bill bugs present on that date were recovered and counted. This incident is merely cited as one of the incidents that force us to the conclusion that the proportion of sexes must be nearly equal under ordinary conditions, in spite of the fact that in the total numbers counted from all sources there are 110 females to every 100 males.

TABLE XIV.

SHOWING THE DISTRIBUTION OF ADULT BILL BUGS ON JUNE 10, 1915. PLOT A—ONE-EIGHTH OF AN ACRE.

	Females	Males
Feeding	2	2
Egg laying	1	0
Actively crawling about	0	1
Under clods, sticks, etc	24	39
Totals	27	42
Per cent	40	60

APPEARANCE OF THE ADULTS IN THE SPRING

In the eastern part of the State the adults appear in the corn-fields as early as mid-April. Their numbers increasing gradually, as the weather grows warmer, so that usually by the first of June all the over-wintering beetles seemed to have emerged from hibernation, and usually towards the end of June their numbers seem to be increased by newly transformed adults which may be readily distinguished at the time of their emergence by their velvety brown color. The numbers of adults increase gradually during July and the first half of August. The bill bugs usually completely disappear in fields of corn planted in April and May by the latter part of August. These bugs seem to locate in later planted corn if any be available, but just where they go if corn is not available has never been definitely determined. Perhaps they

feed upon some of the wild food plants, but close observation fails to show any especial increase in their numbers in such situations. Neither can any be found in the usual hibernation situations save young beetles which have evidently not yet emerged from their pupal cells.

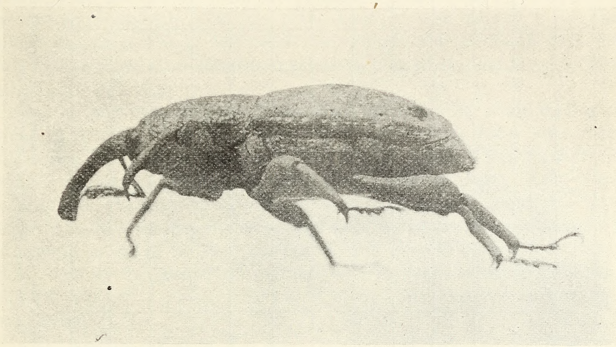


FIGURE 61. Adult lateral view. X6.

DIURNAL ACTIVITY

The diurnal activity of corn bill bugs in the field was made a special point for investigation during the summer of 1912, and since that time many additional observations have been made which support the conclusions drawn at that time. In making these observations, 627 adults, 329 of which were females and 298 were males, were marked in various ways and studied throughout the month of July and part of August. These adults, it is believed, represented all of the individuals present on a plat of about one-third of an acre in extent. Observations were made at various times for every hour of the day and night. From these observations we have concluded that there are two main periods of activity for the corn bill bug, the activities for the most part consisting of feeding and egg laying for the female and feeding and mating for the males. For a fuller discussion of these activities, see habits of adults below. Two main daily periods of activity are followed by two periods of inactivity, when the bill bugs crawl away under any shelter that may present itself, such as clods, partially buried sticks or pieces of cornstalks and stones. The activities vary somewhat from month to month and from day to day. But the activities on a cool, cloudy day late in the season approximate the activities on a warm, bright day early in the season. I have attempted to reduce all of these observations to the form of a curve (Fig. 62).

In order that all of the observations made during the summer of 1912 and during the following summers might be correlated, the ob-

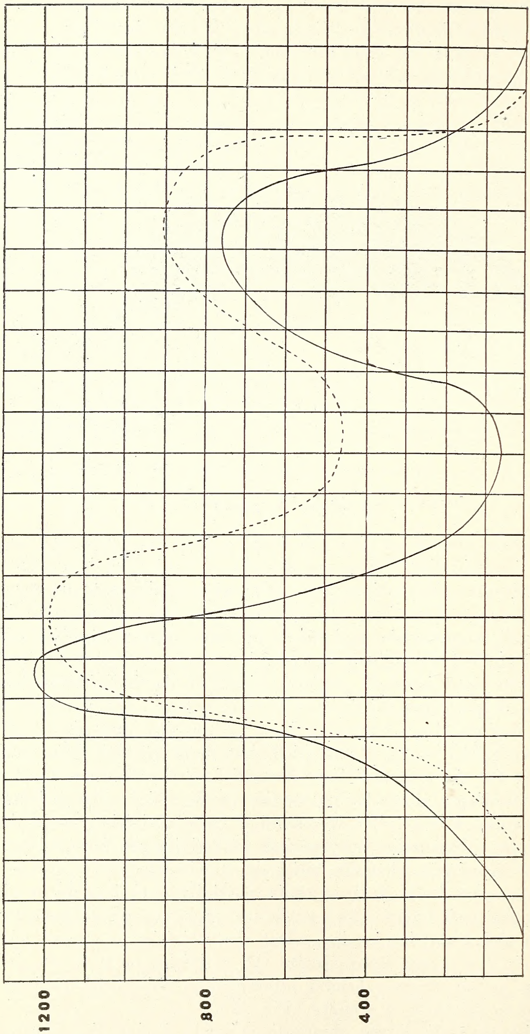


FIGURE 62. Curve to show diurnal activity based on counts as made in the field. Solid line (———) to represent activity from mid to late season. Dashed line (— — — —) to represent activity early in the season. On the basis of hundreds active per acre.

servations on the diurnal activities for bill bugs have been reduced to a curve representing the numbers of bill bugs active per acre. This curve does not take into consideration the number of bill bugs that were not active, as it was impossible to be absolutely sure whether you had actually secured all of the inactive bugs lying under clods and in similar situations. On the other hand, it was usually a comparatively simple matter to determine the number of bugs which were feeding, laying eggs, or otherwise engaged in any of the daily activities of adult corn bill bugs.

On the plat where most of the observations were made during the summer of 1912, 627 adult corn bill bugs of both sexes were found. This plat represented about one-third of an acre. Thus we have bill bugs occurring at the rate of more than 1,800 per acre. Yet in spite of this fact, the average rate per acre at the period of greatest activity, about 8 a. m., was usually not more than 1,200 per acre. Some other observations made in 1913 confirmed this general conclusion, that is, that even at the period of greatest activity only about two-thirds of the bill bugs in a given area would be actively engaged in feeding or egg laying.

From an inspection of Fig. 62 it will be observed that on the average bright day in mid-season the two main periods of activity are from 6 to 9 a. m. and from 4 to 8 p. m. The main periods of inactivity are from 10 a. m. to 3 p. m. and again from 10 p. m. to 3 a. m. Ordinarily on bright days no bill bugs will be found active from 11 p. m. to after 2 a. m. The first bill bugs become active between 2 and 3 a. m., these being joined by others between 3 and 4. a. m. So that on the average there are about 200 active bill bugs per acre by 4 a. m. Usually by 5 a. m. another 100 per acre have joined those already at work; by 6 a. m. the number of active bill bugs per acre has usually increased to 600, and by 7 o'clock this has usually doubled again; so that there are on the average about 1,200 bill bugs per acre actively engaged in feeding and egg laying. By this time some of the earlier ones to become active have begun to seek shelter, but usually there are enough more becoming active, so that up to 8 o'clock the numbers are about constant. Very few new ones join the ranks after 8 o'clock, so that the numbers drop off rather rapidly, and late in the season, during late July and early August, on clear days when the sun is very hot in the corn-fields practically all of the bill bugs will be under cover by 11 a. m., where practically all will remain until about 2 p. m. In mid-season, mid-June to mid-July, the later arrivals in the morning will linger through the warmer part of the day, so that it is not unusual to find bill bugs at the rate of 200 to 300 per acre at this time of the day.

Still earlier in the season, as from mid-May to mid-June, and on cloudy days later in the season, the bill bugs do not become very active until about 6 o'clock in the morning, but by this time there are usually

at the rate of 500 bill bugs per acre actively at work in the field. This number increases to nearly 1,200 per acre by 8 o'clock; this number remaining practically constant until 10 o'clock, when the number actively at work usually falls off rather rapidly to about 500 per acre at 12 o'clock. This number remains practically constant until about 3 o'clock, when the numbers commence to increase gradually up to from 900 to 1,000 by 5 o'clock. This number remains practically constant until 7 o'clock, when the number decreases very rapidly, so that by 9 o'clock practically every bill bug in the field has ceased his activities for the day, and if the weather remains cloudy these activities are not resumed until the following morning between 3 and 4, when a few of the earliest to cease their activities then again become active for the new day.

HABITS OF THE ADULTS

The egg-laying habits of adults are touched upon in another connection (see methods of oviposition below) and the general daily activities of adult bill bugs have been discussed under the heading of diurnal activities. However, the general feeding, mating, and other habits have not been discussed.

In discussing the habits of bill bugs one is almost forced to use terms which have long been used to denote conscious human actions. The writer has no intention of implying that either the stimulus or the reaction is the same as it would be in human beings, to produce the results described. He has merely used these terms because they happen to give the clearest picture of the reactions of bill bugs to certain complexes of stimuli.

The adults feed at or near the level of the ground, tearing away the outer leaves of the plant so as to be able to get at the tender growing leaves or bud of the plant. In feeding, the bill bug always assumes a position with head downward. When the plant is young the bill bug may feed at a distance of an inch or two above the surface of the soil, but usually they have the head and thorax below the surface and not infrequently practically the whole body will be below the surface. Occasionally the adults are so completely buried that their presence is not suspected until the plant is pulled up, when the adult will be found clinging to the portion of the stem below ground. Usually, however, a portion of the pygidium is left exposed, so that close observation will reveal the presence of the adult. This, however, requires very close inspection, for, as explained above, the color of the bill bug very closely approximates the soil in which it is living, due to the fact that small particles of the soil adhere to the body.

The bill bug is not easy to dislodge from the corn plant while it is feeding. When disturbed it clings to the stalk of corn by means of the tibial spines, so that usually part of the stalk of corn is torn away before the bill bug is removed.

In its movements the bill bug is very slow and deliberate, evidently depending upon its color and slow gait for protection. At times the adult moves rather rapidly, but this gait is not long continued, and usually after each period of rapid movement it will remain perfectly motionless for a period usually equaling if not exceeding the period of rapid movements. This jerky gait always impresses one with the thought that the bill bug fully expects every movement it makes to betray it to its enemies. Their total movements thus become so slow as to exhaust the patience of any human being who is observing them in the hope that he will get a composite picture of their activities. The same slowness of gait applies to all of their activities, be it mating, egg laying, feeding, or what not. All of the movements of the bill bug seem to be entirely aimless and without any definite purpose, or such is my conclusion, after watching them for the past several seasons both in the field and in the insectary. In the field bill bugs on coming from their retreats under clods or sticks will proceed in a jerky manner often for a distance of many feet, often passing in their wanderings within a fraction of an inch of stalks of corn, to bring up eventually at a stalk that is, so far as one can observe, not better in any way than stalks that have just been passed. Frequently they will take such journeys of exploration, sometimes wandering across a plat of corn thirty or more feet in direct line from the starting point, only to turn in an aimless fashion, partly retracing their steps and winding up at a stalk of corn within a few inches of their retreat, where they will commence to feed and continue to feed long after their companions have sought their shelters for their noontime siestas. These aimless wanderings seem decidedly more common during the morning hours than they are during the evening hours. It is for all the world as if these fellows had after a night's rest arisen refreshed in body and started out on a journey of adventure to the far recesses of their domain. At first it was supposed that these wanderings were for the purpose of seeking mates, but, so far as our observations go, bill bugs possessed with this wander-lust do not seek mates. In fact, in the majority of cases, as discussed below, coupling seems ordinarily to take place before the bill bugs emerge from their retreats.

The mating habits of the bill bugs are rather interesting. The males for the most part seek the females while they are still in their retreats. Coupling takes place usually at this time. Actual copulation does not usually take place until the bill bugs have come out from their retreats, the female carrying the male about until she has found a suitable stalk in which to oviposit. Then, while the females are making the egg cavity, copulation usually takes place. Copulation is usually completed long before the egg cavity is completed; the male, however, may continue to cling to the female for a considerable time after copulation, not infrequently clinging until oviposition is completed and sometimes clinging until the female starts another egg cavity. Sooner or later,

however, the male releases his hold on the female, usually crawling away to another stalk of corn, where he commences to feed, or, if the day be well advanced, he may return directly to a retreat. This results in very promiscuous matings, for in no case have the same individuals been found mated on consecutive days.

The time spent by individuals in feeding on a given plant varies greatly. Usually bill bugs after becoming established on a plant will remain as long as an hour, frequently for several hours. Records have been made of bill bugs feeding on the same plant for at least twelve hours, but such prolonged periods are rather unusual. In all such cases the bill bugs have been protected from the hot rays of the sun by overhanging corn leaves or they have been protected by being in a group of cornstalks.

In approaching a stalk for feeding purposes, the bill bug seems to locate it merely by accident, often passing within a fraction of an inch of a stalk that is apparently as good as the one finally selected. So far as observed, a stalk had to be directly in the path of the bill bug before it was selected. Frequently observations were made which would lead one to believe that if the bill bug could not escape it would proceed to feed on a stalk of corn that directly blocked its path. No cases have been observed of a bill bug emerging from its retreat and going directly to any stalk of corn; and in very few cases was the stalk of corn nearest the retreat selected, and then only after aimless wanderings, which usually caused the bill bug to cover many times the distance required. When an adult finds its path directly blocked by a stalk of corn it pauses for a longer or shorter period of time. Eventually it crawls up the stalk for a short distance, usually from one and a half to two times the length of its body, then turns deliberately around with the center of its body as a pivot until its body is parallel with the long axis of the cornstalk, with head downward. Usually it is then half the length of its body above the surface of the ground. It then crawls down the stalk until it reaches the surface of the ground, when it may insert its snout into the stalk or it may bury itself partially or completely below the surface of the soil.[1] In making the egg-laying punctures the jaws usually tear away portions of the outside leaves, but in making feeding punctures the bugs seem for the most part to devour the substance of the stalk as the snout is inserted deeper into the stalk.

OVIPOSITION

Age of Adults At Beginning

In the insectary during the summer of 1915 all the female beetles commenced to lay eggs within two weeks of the time of emergence from the pupal cells, if they were provided with suitable food. Inasmuch as the beetles usually linger in the pupal cells from five to seven days after they have transformed to adults, we are justified in saying that adult

females commence laying from two to three weeks after they have transformed. This would mean, then, that the first adults that emerge in the early summer would commence to lay eggs that season and continue right through with their parents; whereas the beetles emerging late in the season would not find suitable corn in which to oviposit and would seek hibernating quarters and not commence egg laying until the following season. This, perhaps, accounts for the great variation in the numbers of eggs laid by individual females. (See egg-laying records above.)

EXAMINATION OF PLANT BEFORE BEGINNING OVIPOSITION

So far as our observations go, the adult female makes no preliminary examination of the plant in which she is going to oviposit. Instead, as discussed above under "Habits of the Adults," she simply seems to take any plant that offers. Neither is there any attempt to avoid plants already containing eggs. In one case, early in the season, a small plant was examined which contained five eggs, yet there were within a radius of six inches not less than four other plants that contained no eggs and many others in the same field near by which contained no eggs or only very few eggs.

The females which are making egg punctures may be readily distinguished in our experience from females that are simply feeding by the following characteristic actions. Feeding adult bill bugs either male or female take their position head downward on the stalk at or below the level of the ground, usually higher on the plant than egg-laying beetles. The body of the feeding beetles, so far as we have observed, remains motionless, the tarsi only being moved and the beak seeming to sink without effort into the stalk. On the other hand, adults preparing egg cavities seem to take a position lower on the stalk than feeding beetles, and, in addition, their bodies are pulled back and pushed forward as the beak is inserted; thus instead of a small round puncture a long oval puncture results, the beak acting somewhat as a wedge to separate the stalk as it is inserted deeper and deeper. While making the egg puncture the adults have their bodies parallel with the long axis of the stems of the plant, with head downward (Fig. 5), but when the egg cavity is finished they turn slowly about with the center of the body as a pivot and locate the egg cavity with the tip of the abdomen (Fig. 6). The tip of the abdomen is then slowly inserted into the cavity, the beetle retaining its hold upon the plant largely by means of the metathoracic and mesothoracic legs. Not infrequently the prothoracic legs are entirely withdrawn from the stalk. Oviposition completed, the beetles simply crawl away, sometimes going to shelters under clods or elsewhere, sometimes wandering about until they locate another stalk upon which they may feed or oviposit.

PLACING THE EGG

So far as our observations go the eggs are laid below the surface of the ground either in the stem of the plant or loosely among the roots. In young plants the eggs are simply placed in cavities eaten into the stem, but in older plants the eggs are carefully inserted in small pockets formed in the heavier outer leaves.

Only a few individuals have been observed to lay more than a single egg per day, but in all individuals observed laying more than one egg per day the first egg laid was deposited more carefully than later eggs. From this we have concluded that females that lay eggs loosely in the ground have deposited more than one egg for that day.

TIME REQUIRED FOR EACH INDIVIDUAL ACT OF OVIPOSITION

No hard and fast rule can be given about the length of time required in each individual act of oviposition. In general, the act may be divided into the following steps: (*a*) locating the plant, (*b*) turning head downward, (*c*) making the egg cavity, (*d*) turning with head up the plant and inserting the ovipositor, (*e*) ovipositing, (*f*) seeking shelter or another plant. Any one of these steps varies greatly with not only different beetles on different days, but with the same beetle at different times of the day and on different days. Any one of the steps may be hastened through in a few minutes or it may be prolonged for an hour or two. Sometimes one process is hastened forward with the greatest dispatch—perhaps, till it is completed; perhaps, till it is only partly completed; to be followed by a period when the beetle evidently does no work at all. If the beetle is disturbed in any way while engaged in any of the processes of ovipositing, it remains perfectly quiet for a longer or shorter period, but in no case observed did the bill bug leave the process of oviposition incompleted unless it was violently removed from the plant on which it was ovipositing.

Many beetles have been timed at all hours of the day, and, as a general rule, beetles are slower to complete the act of oviposition in the morning than they are in the evening, and slower in the evening than they are during the middle of the day. The following example of a bill bug observed almost constantly from about 6:50 a. m. until 11:45 a. m., during which time she laid two eggs, will be fairly illustrative of the time involved in the various steps of the whole process: An adult female, attended by a male, was first noted near a clod, under which there were two other females and a male, about 6:50; wandered aimlessly about until 7:05, when she approached a plant: end of step *a*. She stood perfectly still at the base of the plant until 7:18, when she started to crawl up the plant, turning around, head downward, this step (*b*) being completed a few seconds before 7:20. Worked on the egg cavity from 7:20 to about 8:05; last observed at 8:00 o'clock, not

again observed until 8:06, when she had withdrawn her beak and had turned her body so that its long axis was at about an angle of 10 degrees to the long axis of the plant. At 8:09 she had completely turned around, so that her abdomen was in the egg cavity, where it remained until 8:40. When the abdomen was withdrawn the male dropped off the back of the female without having copulated, and, after rolling away from the cornstalk a distance of three or four inches, crawled away to a stalk in the next row of corn and commenced feeding. The female remained with head up the stalk until about 8:50, when she started away in the opposite direction, proceeding in the usual manner of adult bill bugs by moving rather rapidly for a few inches, then remaining motionless for a longer or shorter period of time. She arrived finally at a stalk of corn in the next row, a distance of less than five feet, at about 10 o'clock; she then remained motionless at the base of the stalk for about 35 minutes, finally turning head downward hastily at 10:35 and commenced an egg-laying puncture. This cavity was completed by 11:15, when she turned around hastily, taking a little less than a minute to insert the tip of her abdomen in the cavity, from which it was withdrawn at 11:29; within another minute she had crawled away from the stalk a distance of three inches, where she remained in the shade cast by a weed until 11:45, where further observations were abandoned for the time. At shortly after 12 o'clock the same female was found under a clod within about five inches of the place where our observations had been abandoned.

EGG AND FEEDING PUNCTURES

If there is a characteristic difference in the method of making egg cavities and feeding punctures, as all our observations would lead us to believe, then we have a ready explanation of the reason that we have two kinds of punctures in the leaves of corn plants that have been injured by the bill bugs, one being circular in outline and the other oblong (Fig. 7). We believe from observations that have been made on young, rapidly growing plants where beetles were permitted to feed only, and in other cases where they were observed to oviposit, that the circular holes represent feeding punctures and the oblong holes represent egg punctures. At one time it was thought that this would enable one to readily determine the number of eggs laid in a field, and then, by carefully counting the number of females, to be able to calculate the average number of eggs laid by females in the field; but this was abandoned when it was discovered that eggs were frequently laid loosely in the ground.

EFFECTS OF THE ADULTS ON CORN

The adults do a great deal of damage to young corn by inserting their beaks into the stem, usually below ground, and eating out the tender forming leaves (Figs. 10 and 63). This soon makes itself apparent by

FIGURE 63. Corn stalk showing characteristic injury by adults.

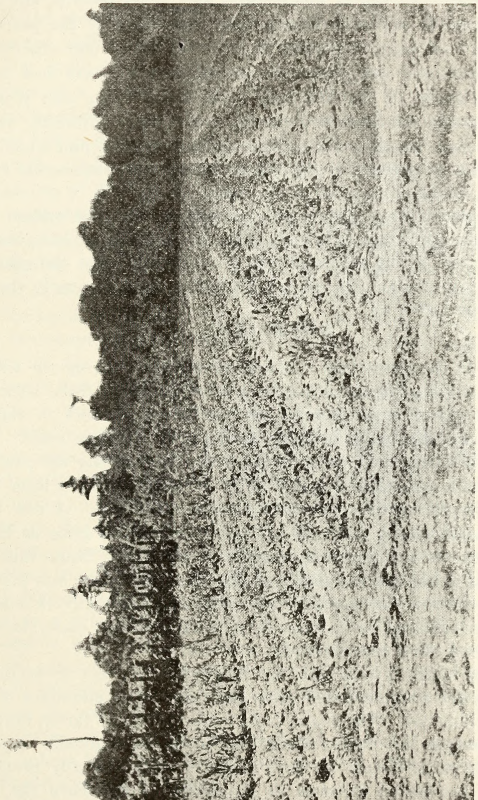


FIGURE 64. Experimental plot showing corn on the left too old to be much injured by adults. Corn on the right being badly injured by adults.

rows of round or oblong holes running across the leaves. Frequently these rows of holes are found in the so-called seed leaf, indicating that the adults often attack corn as soon as it appears above ground. When young plants are attacked in this manner they never recover, but simply die. It is hard to arrive at a satisfactory estimate of the percentage of plants that are injured in this way, for in all of our experimental plats planted to test this phase of the problem we have had to deal with bad outbreaks of the Southern Corn Root-Worm, and while the methods of attack of these two insects are entirely different, yet frequently the same plants are attacked by both insects and under such conditions it is impossible to say which insect was responsible for the death of the plant.

After the plants have grown to some extent they are seldom killed outright by the adult corn bill bugs (Fig. 64). Their growth, however, is much stunted if the adults attack it frequently; but the adults do not seem to injure corn after it has started to grow to nearly the same extent that the larvæ do.

HIBERNATION

The adult is the only stage that has been found during the hibernation period. Hibernating adults have been found in three situations: among the roots of cyperus grass, in the larval burrows in stalks of corn, and in the pupal cells in the ground among the corn roots. Many hibernating bill bugs have been found in the field during the past three winters, and of the number found fully 90 per cent have been in the pupal cells in the earth underneath the corn stubbles. A few beetles have been found among the roots of clumps of cyperus grass at Raleigh and a few have been found in cornstalks at Willard. Those that occur in pupal cells in the ground seem for the most part to be late maturing beetles, and are more common in late corn, and especially in late corn that has been retarded in its growth, as corn growing under trees and in poor soil and other like situations.

The adults in the pupal cells in the ground are apt to occur anywhere among the roots, but they seem to be especially abundant directly beneath the tap-root. The former, perhaps, represent larvæ that have developed among the roots, while the latter undoubtedly represent larvæ that have developed in the stalk; for in practically every case where there are larval burrows in the stalks of late corn the adults will be found in pupal cells near the tap-root. On the other hand, farther away from the tap-root there are usually no evidences of larval burrows in the stalk. Most of the pupal cells in the ground are situated rather deep, usually an inch or two below the bottom of the cavity caused by pulling up the stubbles. In fact, it is very rarely that one finds a hibernating beetle by pulling up the corn stubbles, unless the beetle happens to be in the larval burrow in the cornstalk. In February, 1913, I pulled up over three hundred corn stubbles in a corn-

field where the corn bill bug damage had been very serious during the summer of 1912, and did not find a single corn bill bug until I took a spade and spaded the stubble out of the ground, taking care to get about three inches below the level where the roots would ordinarily break if the stubble had been pulled out directly. Then by carefully splitting the stalk lengthwise and dividing the soil below the tap-root, a bill bug could be found under practically every stalk that showed indications of a larval burrow. This occurred in about 60 per cent of the stalks in the same part of the field and in adjacent rows to those where we had pulled up over three hundred stalks and had not found a single adult. Occasionally one would find the lump of soil sometimes at a distance of five or six inches from the tap root. Perhaps more beetles occurred in such situations than we actually observed, for in the winter, when bill bugs are inactive, they are exceedingly difficult to distinguish from lumps of earth. When one was found in such situations it was usually due to the fact that the lump of earth adhering to the roots happened to break across the pupal cell, which would usually be conspicuous because it was a cavity with a smooth surface. Discovery of the pupal cell usually led to the discovery of the beetle; sometimes it was found projecting from the other half of the cell, but more often it was found among other little lumps of earth, from which it could usually only be distinguished by individual examination.

Thus it seems safe to conclude thta the beetle stage is the only one that ordinarily passes the winter, for many adults have been discovered in hibernation and no other stages have been found. The only apparent exception to this statement is the record of a single pupa found by Mr. Hyslop, as recorded below; but, as explained elsewhere, the larvæ that develop from the last eggs laid in corn undoubtedly do not reach maturity before early November; hence this record would have to be excluded as a hibernating individual. Of the individuals that have been found in hibernating quarters, about 90 per cent were in pupal cells in the ground below the tap-root and about 2 per cent in the larval burrows in the stalks, and a little more than 7 per cent were in pupal cells among the roots.

The peculiar situation of the pupal cells perhaps accounts for the fact that others have had difficulty in locating hibernating bill bugs, as Mr. Smith's record will show.

"The bill bugs hibernate ordinarily in the beetle stage. This statement is made without reservation and is based on many field observations during the winter of 1909-1910, when careful search on several occasions failed to reveal any eggs, larvæ, or pupæ in the field where bill bugs were known to have bred during the previous falls. It has proved to be extremely difficult to find any bill bugs in their winter quarters, but the total absence of larvæ and pupæ in the breeding places proves that the winter is not passed in either of those stages.

"Only one record has been secured of actually finding the beetles in a place where they presumably pass the winter. On November 4 and 5, 1911, in company with Mr. J. A. Hyslop of the National Bureau of Entomology, adult bill bugs were found in corn stubble in a field on Harvey's Neck in Perquimans County. The trip to this field was made for the express purpose of trying to find the beetles, for it was assumed if any were found on that date that they would be in hibernation for the winter. After considerable search we located a dead beetle in a cornstalk. This beetle was at a point in the stalk about even with the surface of the ground. Soon afterwards we found another dead beetle in a similar location. On the second day three live beetles were found in cornstalks in a field where serious bill bug damage had occurred during the summer. Apparently these beetles had matured late and had not attempted to escape. We consider this to be proof of the hibernation actually occurring in the cornstalks. The beetles were in the stalk near the roots where the larva had fed and transformed.

"During these two days when beetles were found in cornstalks, we also searched for the beetles and the immature stages, in cyperus plants, but without success. In fact, there were only a few cyperus plants found in which Sphenophorus larvæ had lived. The writer believes, however, that the bill bugs had bred in cyperus in these fields in plants that had died down and become invisible.

"Hibernation must also occur in the soil, or under the protection of some material in the fields, as well as in cornstalks. The breeding of beetles during the past summer, when every reared specimen emerged and fed nearly every day thereafter until the middle of November, shows that it is the natural thing for the beetles to come out and feed after maturity. If this is true, the majority of the bill bugs are not hibernating in cornstalks unless they crawl into the stalk when cold weather commences. That this actually occurs is extremely doubtful. The beetles found in the cornstalks had certainly never emerged, and no beetles were found under conditions to indicate that they had crawled into the stalk.

"On November, 5, 1911, Mr. Hyslop found one healthy live pupa in a cornstalk. This indicates a possibility of the pupæ living in that situation all winter. The rearing records, however, do not indicate that pupæ are liable to live all winter. This point needs further investigation, but in view of present knowledge we may consider that only the mature beetles normally live during the winter.

"The writer has searched for the beetles in winter quarters in fields at Lumberton, Chadbourn, Braswell, Pembroke, and other places, including the fields around West Raleigh, where many bill bugs bred during the last two seasons. Without recording details of the work, it may be stated that the beetles have never been discovered during the winter months, that is, December to March, inclusive, except in one instance, at Chadbourn, when a single specimen was taken in the

edge of a rice field on March 29, 1911. On that date one beetle was found in a clump of grass, where it was moving about; hence it was not exactly in hibernation. Sticks, stones, logs, dead grass and weeds, brush, and, in fact, every movable thing in the field, have been overturned in the search for beetles in hibernating quarters other than cornstalks."

Just what becomes of the early maturing adults has never been determined. During mid-season the adults seem to emerge from the pupal cells in from five to seven days after transformation; later in the season this time seems to be gradually extended, and the late beetles remain in the pupal cells all winter. The writer believes that the early maturing beetles leave the cornfield late in the season, especially if the corn has been planted early, and migrate to later corn or to adjacent patches of cyperus grass, where they undoubtedly go into hibernation anywhere in the field a few inches below the surface. No beetles have been found save those that were still in pupal cells, in spite of the fact that we have sifted the top five or six inches of soil in many different parts of various cornfields that had been badly infested with bill bugs the previous season. Any one, however, who has had any experience with bill bugs in the field will appreciate the difficulties involved in attempting to locate bill bugs by sifting, and it is not at all remarkable that we were unable to locate them.

BEETLES FROM EMERGENCE TO HIBERNATION

Just where the early maturing adults spend their time from the time when they emerge from the pupal cells till they go into hibernation is still in part an unsolved problem. Part of the adults, evidently late maturing ones, remain in the pupal cells over winter; and part of the early maturing adults emerge from their pupal cells and feed in the same fields with their parents. Whether these young beetles lay any eggs the first season or not is discussed in another connection.

In fields of early or medium early planted corn the corn reached maturity in early September, and in such fields all the adult bill bugs have practically disappeared by late August. In later planted corn, especially in extremely late corn, the stalks may stay green and tender until after heavy frost, and the adults continue in such fields until late October, at least, evidently not seeking hibernation quarters until early November. In most cases, however, no such late corn is available, and it therefore becomes a problem to determine just where the adult bill bugs live from late August to early November. In the hope that we would be able to solve this problem, something in the neighborhood of five hundred pairs of adult corn bill bugs were marked in various ways in early August, 1912.

The adults marked in 1912 had a spot of bright water color painted either on the thorax or the elytra, as this method of marking had been

previously tried out very successfully in studying the diurnal activities. However, none of these beetles were ever seen after the last of August. Believing that the water-color paint used during 1912 might have been removed in the ordinary daily activities of the beetles, other pairs were marked by clipping their elytra during August, 1913 and 1914. None of these beetles were seen after mid-September and only a few after late August. Not many were ever seen far from the place where they had been marked, although a few were recovered in adjacent fields. None of the beetles marked in 1913 were recovered in 1914, and none of those marked in 1914 were seen in the spring of 1915.

However, in spite of this negative evidence, the writer is of the opinion that the beetles leave the early corn-fields in late August, either traveling to late fields of corn or to patches of cyperus grasses. This conclusion is strengthened by the fact that the bill bugs seem to disappear from the corn-fields very suddenly, and there is some very strong evidence from observations made in the insectary to show that late in the season the adults seem to develop a sudden instinct to fly. This is perhaps true in the field, also, and would naturally account for the sudden disappearance of the beetles from the corn-fields, as in the insectary all the beetles seem to acquire the instinct to fly at about the same time.

We have made no direct observations in the field that the beetles fly, save the indirect deductions as outlined above. If the beetles do acquire the instinct to fly from the fields, it would aid very materially in dispersing the species and would be a very important phase in their life cycle.

Careful counts of the numbers of beetles per acre have been made on small plats averaging one-third acre each. In these counts an effort was made to secure every beetle present in the field. Some were undoubtedly missed, but our counts usually showed an average of about 1,100 beetles per acre in mid-August, this number dropping so suddenly that by the last week in August there would be on the average from 75 to 100 beetles present per acre.

MORTALITY DURING HIBERNATION

The mortality during hibernation has varied greatly in our insectary experiments. It has ranged from about 10 per cent in some cages to over 90 per cent in other cages. Beetles for our hibernation experiments were placed in various kinds of cages. Some were placed in jelly glasses with varying amounts of sand and varying numbers of beetles in each glass. The mortality seemed to increase with the increased numbers of beetles in a single jelly glass. Some beetles have been held over winter in large screened cages, where they had on the average about six inches of soil in which to bury themselves. These cages were exposed out of doors, and the beetles usually went into the

soil to a depth of from four to five inches. In those cages that were left undisturbed the mortality was usually only about 10 per cent. A single disturbance of the beetles seemed to increase the mortality very much, and in cages where the beetles were disturbed several times they all died.

In the fields careful counts of plats averaging about one-third acre show that normally the numbers decrease from a rate of about 1,250 per acre in July of one season to about 420 per acre by the end of May the following season, by which time it is believed all of the adults have emerged from hibernation. This would give a mortality of about 66 per cent, provided all the beetles returned to the same fields; but, as pointed out in another connection, we have not been able to prove that any of the beetles returned to the same fields in which they worked the previous season, although, in spite of our negative evidence, some beetles undoubtedly do return to the same fields.

NATURAL ENEMIES

The corn bill bug is singularly devoid of natural enemies in all its stages. So far in these investigations no parasitic enemies of any of the stages of the bill bug have been discovered, and only a very few predaceous enemies. In the corn-fields in the eastern part of the State adults and larvæ or various species of ground beetles, lampyrid beetles, digger wasps, robber flies, and other predaceous insects, abound. Various species and individuals of these predaceous insects have been watched often for considerable periods. There is no indication that these insects prey upon any of the stages of the corn bill bug. Even when eggs, larvæ, and pupæ were exposed directly in the path of these predaceous insects they made no effort to devour them.

The little brown corn-field ant is also constantly present in the fields, and these have frequently been observed with eggs of the corn bill bug in their jaws, evidently having picked up eggs that were carelessly deposited or that had been deposited in the ground among the roots. There is no evidence that this ant enters the egg cavities and removes eggs that have been carefully deposited, although they are constantly running up and down the stems of corn plants, especially corn plants infested with root lice. In fact, the eggs are for the most part so well placed that it is rather doubtful whether ants would be able to secure any carefully placed eggs. However, ants have been seen with eggs so frequently in the field that one is led to suspect that they destroy a great many eggs in this way. Mr. Smith well says (Smith, 1913): "An egg dropped or placed on the ground or exposed on the plants is very quickly taken away by the little field ants. Just how much benefit they cause by destroying the eggs the writer has not had a chance to discover."

In October, 1915, I chanced upon the following observation, which is given in some detail because insect enemies of the corn bill bug are so

rare. In pulling up a stalk of corn in a field which had been planted in early July, I discovered a larval Tabanid firmly anchored to a larva of a corn bill bug of large size which was evidently nearly ready to pupate. It took considerable force to dislodge the Tabanid larva, which was placed in a tight tin box with four other good-sized corn bill bug larvæ and two pupæ. After a few minutes the box was examined and the Tabanid larva had again attached itself by its mouth-parts to one of the corn bill bug larva. The box was placed together with some other boxes and brought back to the laboratory, where opportunity was not offered for an examination until the following day. By this time the Tabanid larva had died, although it had completely eaten the four larvæ and one of the pupæ with the exception of the hard outer chiten and had eaten a hole into the side of the other pupa.

On the face of this observation it would look as if Tabanid larvæ might be very important enemies of Sphenophorus larvæ and pupæ, especially those that are exposed in the ground among the roots of the corn plant, for the predaceous habits of Tabanids are well known and they both occupy the same sort of situations generally, *i. e.,* moist, swampy situations, and must, therefore, be thrown constantly in contact. However, this single observation is the only evidence we have bearing on this point, and we have examined hundreds of larvæ and pupæ in the fields both in cyperus swamps where the natural conditions for the Tabanid larvæ would be good and in corn-fields where the natural conditions would not be so good. The same day the above observations were made we spent much time searching for other Tabanid larvæ, but none were found either in the field where corn bill bug larvæ abounded or along the ditch banks under very favorable conditions for Tabanid larvæ.

Mr. Smith was much troubled in his investigations by a small mite which invaded the insectary. Of these mites he makes the following statement (Smith, 1913):

"Mites have proved to be a pest of both the larvæ and the pupæ in confinement; but field observations do not show that the same thing is true under perfectly normal conditions. During the breeding work many larvæ are apparently killed, or worried so as to prevent regular growth, by a small mite identified by Mr. Banks as *Tyroglyphus americanus* Bks. These mites were often found on the bodies, or in their feeding channels, and usually such larvæ did not grow well. Very young larvæ were sometimes killed by the mites."

During 1913 the insectary was moved and we have had no further trouble with this mite. Neither has the mite ever been observed in the field in the natural burrows.

A good deal of trouble has been experienced in our breeding work with both larvæ and pupæ, which had apparently died from attack of some fungous growth. However, such larvæ were usually found in stalks of corn that were badly decayed or molded, and the chances are

that the larvæ had died from the want of proper food and the fungus had only attacked the larvæ or the pupæ secondarily. Concerning this point, Webster (1912) quotes Dr. Chittenden as follows:

"In another instance, during the last week of August, larvæ of this same species were dying and specimens were referred to Dr. Haven Metcalf, a Pathologist in the Bureau of Plant Industry, who stated that they were apparently free from fungi, and that while there was a possibility of the presence of a bacterial disease, such presence could not be established at that stage. Examination, however, revealed the fact that the bodies of the larvæ were fairly reeking with nematodes, and it is not impossible that these are the cause of the insect fatality."

In our observations no nematodes have been found either in the insectary or in the field. A condition similar to the above seems to be very prevalent among young larvæ, especially late in the season, and for this reason we have concluded that the death of the larvæ was due to poor food.

Toads also abound in corn-fields infested with corn bill bugs, but there are no direct observations to show that toads eat corn bill bugs in any stage. Neither has the examination of toads' stomachs revealed the presence of bill bugs. As a matter of fact, from direct observations one would almost conclude that the toad's eyesight was not good enough to distinguish the slow moving bill bug, whose natural color is so similar to the soil in which it lives. Attempts to feed bill bugs to toads have always resulted in the toad ignoring the bill bug.

Only one bird other than the domesticated fowls has been recorded as feeding on corn bill bugs. According to Webster (1912), "Mr. W. L. McAtee of the Biological Survey has recorded the findings of *Sphenophorus callosus* in the stomach of the nighthawk (*Chlordeiles acutipennis texensis*) at Wallaceville, Texas, August 4, 1907. This is the only exact record obtainable of the eating of this species by birds."

Nighthawks are very common in the eastern part of this State, especially late in the season. But their well known habits of catching their prey on the wing has earned for them the distinctive name, "Bull Bat." This habit would seem to preclude these birds from being considered as important enemies of the bill bugs, unless, as pointed out in another connection, the bill bug has a fall dispersal flight, which would naturally come at about the same time as the greatest abundance of nighthawks, due to their southern migration.

Chickens and turkeys are believed by many farmers to be important enemies of bill bugs, and this may well be true, but we have made no direct observations on this point. One farmer in the eastern part of the State says that several years ago he had to yard his chickens to prevent them from running in a corn-field badly infested with corn bill bugs, for the bill bugs frequently lodged in the throat of the chickens or apparently attached themselves to the tongues with their sharp mandibles in such a way as to choke the chickens.

CONTROL

The control of the corn bill bug is not an especially easy farm practice. This is due to a number of different factors. In the first place, the insect cannot be attacked by any direct remedies, both because of its hardiness and because most of its life is spent in the stalk of corn or buried beneath the ground. The only direct method that might be used to any avail against this insect is hand picking of the adults in the early spring and destroying them by throwing them into boiling water or kerosene. This practice would be too expensive to use on general crop corn, but might be used in small fields of corn which were being grown for roasting-ear purposes. If this method were to be used it would be advisable to scatter chips about the field under which the bugs would crawl during the middle of the day and from which they could be collected readily.

In the main the farmer in the bill bug section of the State will have to depend upon a slight modification of his usual farm practice to control the corn bill bug.

Careful observations made during the past several seasons show quite clearly that the control is not a very easy matter. It has also been clearly demonstrated that no one method can be used with any great success against this insect, but rather that the control is dependent upon a number of factors which, taken together, give us a system of corn farming somewhat different from the systems practiced in the corn bill bug section at the present time. These factors are discussed separately in some detail below, but it must be emphasized again that the farmer cannot put his dependence in any one method alone, but, instead, that he must work out a system of corn farming with these various factors in mind. In this connection it must also be emphasized here that a system which is built upon a basis of the factors here given is not necessarily a good system for growing corn in all sections of the State under all conditions, but rather that this is the system the farmer should employ in the corn bill bug sections of the State if he hopes to grow corn with the minimum of loss by corn bill bugs. Neither is it intended to imply that this system will avoid the attacks of other insect enemies of corn, but is simply to be used where the corn bill bug is the most important insect enemy of corn. The writer believes that the farmer who follows this system will also be doing the most important things in the control of many of the more important insect enemies of corn; but there are so many factors involved both in the many varieties of insect pests and climatic and other conditions which have not been studied in detail that it would not be surprising if certain insects were not controlled by following the suggestions as outlined here.

The writer believes that the following are the most important factors involved in any system for the control of the corn bill bug, both from the standpoint of ease and cheapness of application: (1) time of plant-

ing, (2) rotation of crops, (3) fertilization, (4) drainage, (5) ridging, (6) fall and winter plowing, (7) thorough cultivation, (8) destruction of native food plants. It will be noted at once that all of these factors are what might be called indirect methods of control. From the very nature of the case it would be impossible to apply any direct methods, for all such methods are expensive and the returns from corn are never great enough to justify the expense involved in their application.

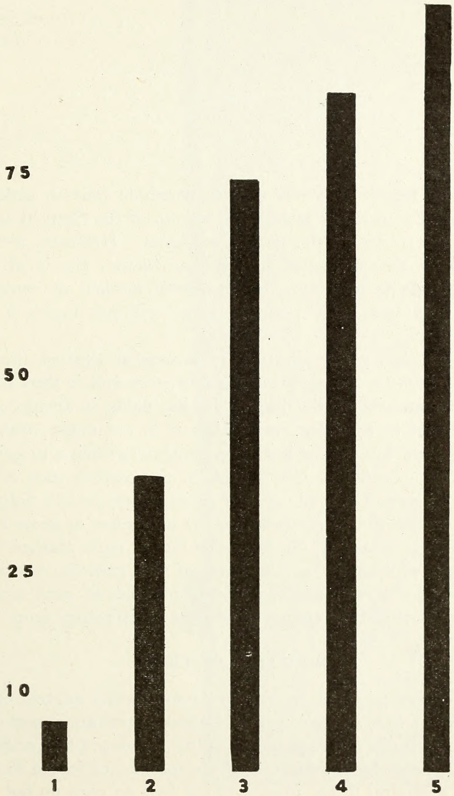


FIGURE 65. Diagram showing the percentage of corn injured when planted at different dates, in Pender County. 1. Corn planted late in March. 2. Corn planted mid April. 3. Corn planted early May. 4. Corn planted early June. 5. Corn planted early July.

TIME OF PLANTING

A series of experiments carried on during 1912 proved very conclusively that time of planting is an important factor in the control of the corn bill bug. Plats of corn were planted on the following dates: March 23, April 13, May 3, June 3, July 3. Careful inspections were made of these plats from time to time, and the following rough percentages will give an indication of the amount of injury:

Date Corn was Planted.	*Percentage Injured.*
March 23	6
April 13	37
May 3	74
June 3	85
July 3	94

From these figures it seems safe to conclude that in order to grow corn successfully in the corn bill bug section of the State it is necessary to plant the corn before the middle of April. However, too much dependence must not be placed in this one factor; for if all the other elements that go to make up the successful method of control of this insect are neglected, early planting alone will not insure a successful crop.

The reason that early planting is successful against this insect is undoubtedly because the early corn gets a start and is thus able to keep ahead of the attacks of the bugs. In the fields it always seems that when corn gets to be about waist high it is no longer much troubled by corn bill bugs, but that it is able to continue growing in spite of their attacks. Corn planted in late March in the eastern part of the State in the usual season has made such a satisfactory growth before the bill bugs come out of winter quarters that it continues to grow right along in spite of their attacks. On the other hand, corn planted after mid-April is just coming up at the time of the greatest prevalence and greatest activity of the adults. Fields planted at such times are so badly damaged that they cannot produce a satisfactory crop.

ROTATION OF CROPS

Rotation of crops is an important factor in the control of the corn bill bug, just as it is in the control of other important insect enemies of farm crops. This is due apparently to two reasons: (1) To the fact that if crops are moved from field to field the insects are forced to move also, because, as a general thing, insects which feed on corn do not feed upon other farm crops. In forcing the insects to move in this way, the chances are that they will not be able to find the new location, and as a result will die for the want of feed. (2) When corn is grown continuously on a field for a number of years the food which the corn requires

Figure 66. Experimental plots on Pender Test Farm showing the advantage of early planting. Corn on extreme left planted late March only very slightly injured. Mid April planting not much injured, but more injured than the late March planting. Next rows to the right planted early May very severely injured. The two rows on the extreme right planted mid May almost completely destroyed.

becomes so exhausted that the corn does not make a satisfactory growth, and hence it readily succumbs to the attacks of insects. Whereas, if proper crop rotation has been practiced, the corn would get a satisfactory start and would be strong and vigorous enough to withstand the attacks of insects to a certain extent at least.

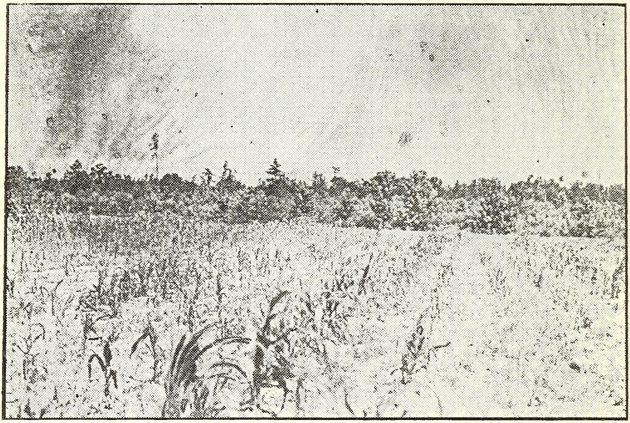


FIGURE 67. Experimental plots showing the effects of heavy applications of complete fertilizers. Row in center and on either edge of plot heavily fertilized. Other rows without fertilization.

FERTILIZATION

Fertilization is, perhaps, next to "time of planting," the most important factor in the control of this insect. This is not, of course, the proper place to enter into a discussion of the proper fertilizer to use for corn, but it has been shown on one of our experimental plats that an application of fertilizer will make the plants grow much more rapidly, and hence be less liable to be fatally injured by the corn bill bug than plants which have not been heavily fertilized (Fig. 67). In the same way a heavy application of lime to land that is sour will make the plants grow much more rapidly and thus escape the attacks of the bill bug. The importance of lime may be further emphasized by the fact that very much of our corn land in the corn bill bug sections of the State is naturally very acid.

The belief so prevalent in the corn bill bug sections that fertilizers act as repellents against the corn bill bug does not seem to be based on facts. Repeated experiments with various mixtures of fertilizers, air-slaked lime, tobacco dust, tobacco extract, and basic slag failed to show that the adult beetle was deterred from feeding and laying eggs in

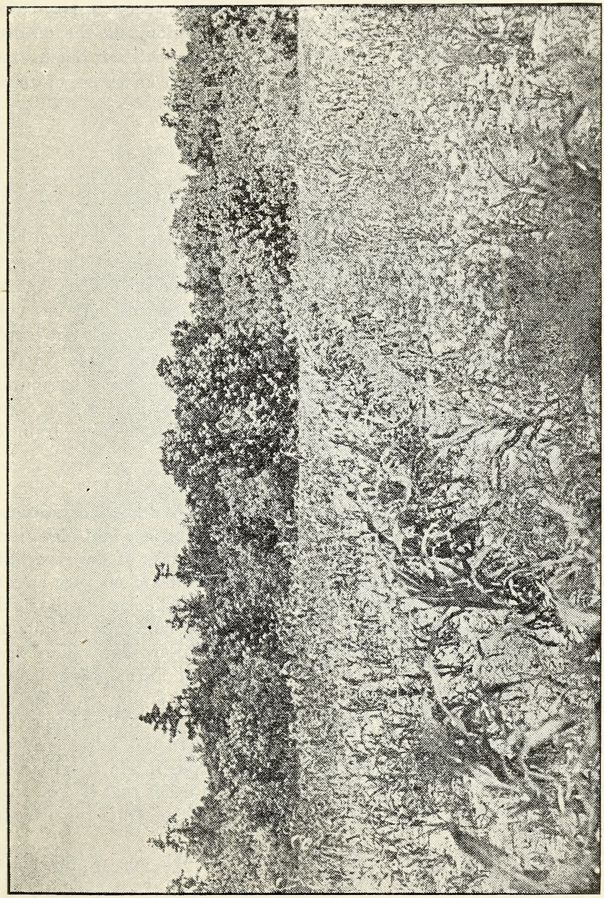


FIGURE 68. Experimental plots to show effect of ridging; row in center and either edge of plot ridged; other rows planted on the level.

plants thus protected. In some cases the material used as a repellent was actually mounded around the base of separate cornstalks, yet the beetles crawled over the mounds of the supposed repellent to feed upon the protected stalk. In all cases where a repellent action has been ascribed to any fertilizer, the writer is of the opinion that the results observed are not due to the repellent action of the fertilizer, but to the fact that such plants are growing rapidly, owing to an excess of food material; hence they escape the attacks of this insect.

DRAINAGE

It is a matter of common observation that the corn bill bug is worse in low wet lands than it is in uplands. Naturally this has led to the statement that the most important factor in the control of the corn bill bug is proper drainage of the land; and while this is an important remedy, its importance might easily be over-emphasized. The Pender Test Farm is exceptionally well tile drained, yet the bill bug has not become a negligible factor on this farm. And while we must not leave the impression that proper drainage is not an important factor in the control of this insect, yet we must caution the farmer against assuming that drainage is all important. It would not be possible for the corn bill bug to be worse than we have observed it on some well drained fields. (Fig. 2.)

RIDGING

Observations made in fields in various parts of the bill bug sections of this State show that stalks of corn which are on a slight elevation above their neighbors nearly always escape the attacks of the corn bill bugs for a longer period. Sometimes stalks which are on very slight elevations will not be attacked, while all the rest of the corn in the field has been very severely injured. The amount of immunity to attack seems to be out of all proportion to the height of the ridge. This was especially noticeable in a field on the Pender Test Farm, where many stumps had been recently pulled. In pulling the stumps a ridge of earth was left around a hole which was usually quite shållow after the plow had passed over it. Corn on this ridge either was immune from attack or was attacked only after all the other stalks in the vicinity had been seriously injured or killed. This led to the belief that if corn was planted on a ridge it would to a certain extent escape from the attacks of the insect.

This method was tried, and three rows through one of the plats (Fig. 68) were planted on a ridge which averaged about eight inches high. Corn was planted on these ridges and in rows between the ridges on June 20th. Careful examination made a month later showed that 45 per cent of the corn on the ridges had been injured, whereas 98 per cent of the corn in the rows between the ridges had been injured. An-

other examination showed that the corn on the ridges had been able to continue its growth and was much more advanced than the corn on the level.

This method is not generally applicable, owing to the cost of constructing ridges. It is mentioned in this connection because it might be used for the growing of early corn for market purposes where the expense involved would not be such an important item. This method must not be confused with the general practice of ridging corn at the time of the last cultivation. In the ridging method as here outlined the corn is planted upon a ridge. This method would be applicable only to lands that are very moist and where bill bugs normally abound, and not to lands that are very dry.

FALL AND WINTER PLOWING

Fall and winter plowings have been tried to a limited extent upon small plats, but no very striking difference could be noted in favor of this practice. However, if most of the adults live over the winter in the fields, the plowing of the land in the late fall or in the winter would disturb them very seriously and would act as a decided check upon their ravages. If, on the other hand, only a small number of beetles live over winter in the corn-fields, then the fall or winter plowing would not be such an important factor in the control of the bill bugs. The writer believes, however, that even if it should be proven that only a fraction of the adults hibernate in the corn-fields, the practice of fall or winter plowing would be profitable as a factor in the control of the corn bill bug where the same field was to be planted to corn two years in succession.

THOROUGH CULTIVATION

It has been stated that frequent shallow cultivation will keep the corn bill bug in control. And there are many things that would lead one to believe that this might be true. As discussed above, the adults spend considerable time hiding away under clods, etc. Therefore, it would seem but logical that cultivation would have a tendency to break up these retreats, and, if the cultivations were frequently made, that they would have a tendency to keep the insects disturbed; and these factors perhaps have some importance. However, a rather long series of observations has led the writer to believe that the effects of cultivation are not upon the bill bugs directly, but are rather upon the corn, causing it to grow more rapidly, and hence to be much more resistant to the attacks of all its pests. Observations show that corn that is well cultivated will generally make a better growth when atacked by corn bill bugs than corn which is improperly cultivated; but, on the other hand, the writer has frequently seen corn succumb to the attacks of this insect when, so far as he could determine, the corn had had the very best of cultural attention. Then, again, counts of the number of bill

bugs per acre made in widely varying localities and ranging from fields in a high state of cultivation through innumerable graduations to fields that had just been cleared and never plowed, but in which the corn had been "stuck," failed to show any constant correlation between the state of cultivation and the number of bill bugs present per acre. During 1915 the corn in the experimental plats on the Pender Test Farm was given very poor cultivation and was badly damaged by corn bill bugs, but the adjacent plats which were devoted to other experiments were given very careful cultivation. Yet, so far as could be determined, both plats were about equally injured. At least, the plats devoted to the other experiments had to be replanted, owing to the great amount of injury by corn bill bugs.

However, the writer does not mean to imply by any of the above statements that corn could be grown as well without cultivation as with proper cultivation. Nothing could be farther from the truth. Yet it does seem worth while to correct a growing misconception to the effect that proper cultivation is an early effective method of control for the corn bill bug.

DESTRUCTION OF NATIVE FOOD PLANTS

The corn bill bug is undoubtedly a native insect, and, like many other insect pests, fed formerly on various kinds of weeds. So far as has been determined, these weeds were mostly grass-like plants, especially the grasses which are closely related to nut grass and chufas. The corn bill bug still continues to feed and breed on these grasses throughout its range in this State. Therefore, corn grown in close proximity to such grasses or in fields where such grasses have been allowed to grow, is more apt to be injured by this insect than corn grown in fields that are free from these grasses.

Therefore, anything that can be done to keep down the native food plants of this insect will be important factors in its control. Many of these grasses are swamp-loving forms. Therefore, as the swampy areas on the farm are brought under better and better drainage these plants will be restricted in area and will therefore furnish less food for the corn bill bug. This will lessen the danger of the insect spreading from its native food plants to corn. In this connection, the farmers in the bill bug sections of the State should pay particular attention to drainage of swampy areas where the native food plants abound, and should also watch, closely, the edges of ditch banks and similar situations to see that such places do not grow up in these grasses which would furnish these pests with an abundance of food and would act as incubators for their increase.

Also, it seems hardly necessary to say that if some other crop would be grown on swamp land for the first year or two after it is cleared, it would have a tendency to reduce the damage done by this insect.

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